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Air Quality Impacts of Transit Improvement, Preferential Lane, and Carpool/Vanpool Programs

Peat, Marwick, Mitchell and Co, Washington, D C

Prepared for

Environmental Protection Agency, Washington, D C Office of Transportation and Land Use Policy

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16. ABSTRACT

This report has been prepared in accordance with Section 108(f) of the Clean Air Act, as amended, August 1977. It is intended to assist urban areas in developing State Implementation Plans and integrating their transportation system management and air quality planning programs as required by FHWA, UMTA, and EPA.

The report analyzes the air quality, travel, energy consumption, economic, and cost impacts of three types of transportation programs: priority treatment for high occupancy vehicles on freeways and arterials; areawide carpool and vanpool programs; and transit fare reductions and service improvements.

Important factors (e.g., meteorological conditions, traffic volumes and speeds and changes in modal choice) likely to influence air quality and emissions for the above programs are also analyzed.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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FINAL REPORT

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EPA Contract No. 68-01-3912

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EXECUTIVE SUMMARY

OBJECTIVE AND SCOPE

This report has been prepared in accordance with Section 108(f) of the Clean Air Act, as amended, August 1977. It is intended to assist urban areas in developing transportation measures for the State Implementation Plan and integrating their transportation system management and air quality planning programs as required by the Federal Highway Administration, the Urban Mass Transportation Administration and the Environmental Protection Agency.

The specific types of short-range transportation programs examined this report include:

- priority treatment for high occupancy vehicles on freeways and arterials;
- areawide carpool and vanpool programs; and
- transit fare reductions and service improvements.

It is important to note that other transportation measures such as inspection and maintenance programs for vehicles, parking controls, traffic operations, and pricing are not covered in this project, but will be the subject of future EPA information reports.

The report is intended to provide information to help urban areas covered by EPA's Transportation Planning Guidelines to:

- assess the applicability and potential of the three classes of TSM programs described above for improving localized and regional air quality;
- estimate and evaluate the cost-effectiveness of such programs and their related travel, energy consumption, cost, and economic impacts; and
- identify key factors (e.g., meteorological conditions, vehicle type distributions and vehicle operating speeds) likely to affect air quality and air pollution emissions.

This information report addresses the above issues at a sketch planning scale of analysis. It can thus be used to identify the relative effectiveness, impacts, and costs of strategies in achieving air quality. Local metropolitan areas will thereby have a capability to explore a broad range of strategies for achieving air quality and to assemble the most promising sets of strategies into comprehensive alternative programs. More detailed transportation and air quality analyses -- with appropriate consideration of specific local circumstances -- will be required to adequately address the effectiveness, impacts, and costs of the comprehensive alternative programs within specific urban areas.

ANALYSIS APPROACH

The report includes a summary and assessment of observed and model-estimated travel impacts associated with the application of reserved freeway/arterial lane, transit, carpool and vanpool programs based on a comprehensive literature review.

Programs within the scope of this project which demonstrated potential for cost-effectively improving either localized or regional air quality were selected for detailed analysis and evaluation based on the findings of the literature review.

In order to quantitatively assess the air quality and related impacts of interest, twenty prototype scenarios were defined to represent "real-world" circumstances in which the alternative programs are typically implemented. The use of prototype scenarios, rather than specific projects which have been implemented provides a more consistent basis for comparing the cost-effectiveness and the magnitudes and characteristics of the associated impacts for the programs of interest. Scenarios were formulated to analyze impacts on both localized (CO) and regional (oxidant) air quality.

FINDINGS

The major findings of the report are summarized below.

Literature Review

Localized Strategies

Based on the findings of the literature review, the strategies which appear to have the best potential for achieving improvements in localized CO air quality include:

- With-flow freeway lanes reserved for buses and carpools;

- Contraflow bus lanes on freeways;
- Metered freeway access ramps with bus by-pass lanes;
- Contraflow bus lanes on major one-way arterial pairs;
- Provision of high level express bus service with reduced fares, operating in mixed traffic on major arterials or freeways;
- Provision of high level express bus service (possibly with reduced fares), combined with a reserved lane for buses and carpools on the appropriate freeway facility; and
- Provision of high level express bus service (possibly with reduced fares), combined with a reserved median lane for buses and bus preemption of traffic signals on an appropriate arterial.

Freeway priority strategies can have significant localized (CO) air quality impacts. For freeway corridors with significant localized CO air quality problems, strategies giving priority treatment to high occupancy vehicles may achieve significant improvements, especially when applied as part of a package of strategies favoring high occupancy vehicles in the corridor.

The arterial strategies which appear to have the highest potential for reducing CO concentrations are reserved median bus lanes with priority signalization and contraflow bus lanes on one-way pairs.

Mass transit improvements, such as fare reductions, comprehensive marketing programs, security and facilities improvements and provision of new or expanded service may contribute to resolving localized CO problems. Expanded radial express bus service can have the most significant impact on air quality, especially when introduced in areas where transit ridership is low and when combined with strategies giving priority treatment to buses. While fare reductions and service improvements tend to be costly, the importance of such strategies lies in their inclusion in a comprehensive plan to improve air quality. Although mass transit improvements by themselves may not have significant impact on air quality, they are an essential element of a comprehensive program intended to encourage the use of high occupancy vehicles and discourage the use of low occupancy vehicles. Thus, it is important to improve the mass transit system to provide alternative means for mobility as other programs, such as parking controls, are implemented to reduce reliance on the private vehicle.

Regional Strategies

To improve regional air quality it is suggested that emphasis be placed on the analysis of integrated areawide ride-sharing programs directed at large employers and including carpool matching, vanpool formation assistance, and promotional components. The findings of the literature review also suggested assessing the regional air quality impacts of implementing the promising radial corridor strategies in several corridors throughout the region.

Well-organized areawide carpool matching programs focusing on large employers may achieve up to five percent reductions in work trip VMT. Employer oriented carpool programs are generally more effective than decentralized areawide programs . Vanpooling programs have also experienced success in certain cases for large employers. With some rare exceptions, it is unlikely that areawide ride-sharing programs will have significant localized air quality impacts.

The air quality impacts of both carpool matching and vanpool programs can be significantly improved by incorporating ride-sharing incentive and single occupancy auto disincentive strategies into the overall program. Such strategies would include preferential parking for pool vehicles, lower rate or free parking for pool vehicles, and special employer incentives for employee pool members.

Assessment of Scenarios

Based on the literature review a total of 20 prototype scenarios were selected for analysis and evaluation. These scenarios were defined to encompass the most promising carpool/vanpool, reserved lane, and transit improvement strategies and combination programs for improving air quality.

Ten of the scenarios deal with strategies which impact specific highway corridors, thus affecting only a limited portion of total regional travel. The analysis of these "localized" scenarios therefore focuses on their carbon monoxide (CO) concentration impacts near the affected highway facilities. The remaining ten scenarios have areawide travel impacts. The analysis of these latter "regional" scenarios thus focuses on their regional pollutant emission impacts.

The scenarios were designed with some systematic variation in assumed travel impacts and area size to facilitate generalizing the project's findings. However, the extent of this planned variation in assumed prototype conditions was limited by the number of scenarios analyzed in total and the need for a minimum degree of uniformity among scenarios (so that impact estimates among different strategies would be comparable).

Localized Scenarios

Exhibit 7 in Section III of this report describes the 10 prototype scenarios selected for analysis of localized CO concentration impacts. The first eight localized scenarios deal with the priority treatment of high occupancy vehicles on freeways, while the last two deal with priority treatment of buses on arterials. The programs being implemented in a scenario typically consist of several complementary actions, such as reserving a freeway lane, expanding express bus service, and providing park-and-ride lots in the corridor. As indicated in Section II, such combinations are typical of actual TSM programs.

Exhibit A summarizes the following impacts of the localized scenarios:

- peak hour vehicle volumes on affected highway facilities;
- peak hour CO concentrations (reflecting vehicle emissions only) for both typical, good and typical, poor dispersion conditions; and
- the capital and annual operating and maintenance costs of the scenarios.

The freeway-based scenarios (Scenarios 1-8) are likely to achieve reductions in overall peak hour corridor traffic volumes ranging between 1.5 percent and 7 percent. The estimated reductions in peak direction, peak hour traffic volumes on the freeways in these scenarios ranged between 3 and 15 percent.

The arterial scenarios analyzed (Scenarios 9 and 10) can also promote 4 to 15 percent reductions in peak hour vehicular volumes. As is true for the freeway scenarios, the attainment of such reductions is highly dependent upon the specific setting in which such strategies may be implemented. However, the percentage reductions in vehicular volumes for arterials are based on smaller base volumes and are not fully comparable to the corridor volumes in the freeway scenarios.

Generally the relative reductions in peak hour CO concentrations (under typical, good dispersion conditions) shown in Exhibit A are several percentage points higher than the corresponding reductions in peak hour corridor vehicle volumes but are generally several percentage points lower than the

EXHIBIT A

SUMMARY OF ESTIMATED IMPACTS FOR THE LOCALIZED PROTOTYPE SCENARIOS

PROTOTYPE SCENARIO		IMPACT ON A.M. PEAK HOUR CORRIDOR VEHICLE VOLUME*		IMPACT ON A.M. PEAK HOUR CO CONCENTRATIONS IN $\mu g/m^3$ AT REFERENCE RECEPTOR, FROM AFFECTED FACILITY EMISSIONS**				PROGRAM COSTS IN 1976 DOLLARS (x1,000)	
				TYPICAL, GOOD DISPERSION†		TYPICAL, POOR DISPERSION†			
ID No.	BRIEF TITLE	BASE PEAK HOUR VOLUME	PERCENT CHANGE	BASE VALUE	CHANGE	BASE VALUE	CHANGE	CAPITAL (ONE-TIME, IMPLEMENTATION)(b)	OPERATING(a) (PER YEAR)
1	Expanded Express Bus Service in Mixed Freeway Traffic; Favorable Impacts	10,667	−1.47%	6,756	−139	8,210	−203	3,168/4,768(b)	1,447
2	Freeway Lane Reserved for Buses and Carpools; Favorable Impacts	10,667	−6.30%	6,756	−664	8,210	−782	3,720/5,360	1,830
3	Ramp Metering and Bus By Pass Lanes; Favorable Impacts	10,667	−3.06%	6,756	−388	8,210	−537	6,224/8,844	1,703
4	Reserved Bus/Pool Lane, Ramp Metering, and Bus By-Pass Lanes; Modest Impacts	10,667	−3.97%†*	6,756	N.A.⊕	8,210	N.A.⊕	4,882/6,482	1,751
5	Reserved Bus/Pool Lane, Ramp Metering, and Bus By-Pass Lanes; Favorable Impacts	10,667	−6.90%	6,756	−603	8,210	−832	6,248/7,868	2,268
6	Contraflow Freeway Lane Reserved for Buses; Favorable Impacts	14,758	−1.69%	4,798	+226	6,758	+277	962	641
7	Contraflow Bus Lane, Expanded Express Bus Service, and Park-and-Ride Lots; Favorable Impacts	14,758	−3.72%	4,798	+100	8,758	+104	3,668/5,288	1,818
8	Contraflow Bus Lane, Expanded Express Bus Service, and Lots; Assuming 70%/30% Directional Split; Favorable Impacts	13,500	−4.07%	4,066	−115	6,748	−161	3,668/5,288	1,818
9	Reserved Arterial Median Lane for Express Buses; Favorable Impacts	3,760	−15.47%	4,904	−779	8,485	−998	3,594/4,134	1,130
10	Contraflow Curb Lane for Local Buses on Pair of One-Way Arterials; Favorable Impacts. [Inbound Arterial/Outbound Arterial]	5,000	−4.40%	3,992 3,349	−532 +365	4,992 4,793	−686 +474	468	123

*On all highway facilities explicitly included in the analysis of the prototype corridor (see diagrams in Exhibit 8); in both directions. Volume is for freeway and/or arterial segments approximately 1 mile out from the CBD (adjacent to the CBD in the case of Scenario 10).

**CO concentration 50 feet from downwind edge of primary corridor facility, based on vehicular emissions from affected facilities only; uninterrupted traffic flow conditions are also assumed. Maximum 8 hour average CO concentrations may be approximated using the procedure in Exhibit 14.

† See Exhibit 11 for a tabular description of these meteorological conditions.

†* This value includes the vehicles originally using the corridor freeway, but estimated as being unable to pass through during peak hour because of flow breakdown caused by congestion.

⊕CO Concentration impacts for Scenario 4 could not be reliably estimated. See Exhibit 10 and text for further explanation.

(a) Represents incremental operating costs

(b) The two capital cost entries represent the range in costs depending upon whether existing parking facilities (e.g., shopping center) or newly constructed facilities are required for park-and-ride lots.

corresponding reductions in peak direction freeway vehicle volumes. In Scenarios 6 and 7, CO concentrations are estimated to increase relative to the base conditions. The increase in CO concentrations in several contraflow reserved freeway lane scenarios reflects the travel and meteorological conditions assumed in those scenarios. The results do not indicate that contraflow lanes, per se, have undesirable air quality effects , but rather illustrate the importance of carefully analyzing the potential air quality effects of implementing a contraflow lane on freeways carrying heavy traffic volumes in the "off-peak" direction.

Both the capital and annual operating and maintenance costs of the localized scenarios are sizeable. As discussed in Section III, the costs of purchasing and operating new buses for express bus service represent a substantial part of the total cost of the scenarios.

Regional Scenarios

Exhibit 9 in Section III of this report and describes the 10 scenarios selected for analysis of regional HC, NO , and CO emission impacts. The first two regional scenarios (11 and 12) deal with areawide carpool/vanpool programs focused on major employers in a prototype medium--sized region (500,000 - 1 million population) and a large region (1 million + population), respectively. Scenarios 13 and 14 deal with the application of a combination freeway corridor strategy (e.g., reserved lanes, express bus, park and ride lots) for several corridors throughout the region. Scenarios 15 and 16 do the same for a combination arterial strategy. The last four strategies involved the combination of both areawide carpool/vanpool and freeway corridor strategy components.

The VMT, emission, fuel consumption, and cost impacts of the 10 regional scenarios are summarized in Exhibit B. Reductions in total regional VMT in the range of 1.0 to 1.9 percent are attributable to Scenarios 11, 12, and 17 through 20 which involve carpool and vanpool programs focusing on large employers. These reductions correspond to reductions of 3 to 6.5 percent in weekday work trip VMT. This represents a substantial shift of low occupancy auto trips to transit, carpools, and vanpools during peak travel periods, which will reduce congestion and conserve energy as shown in Exihibit B. These same scenarios are also estimated to yield the largest reductions in regional HC, NO , and CO emissions.

Scenarios 13 through 17, which involve the implementation of reserved lanes on multiple radial freeways or arterials in a region, generally resulted in total regional and work trip VMT reductions of less than 0.5 percent and 1.5 percent, respectively. The small reductions in VMT are in

EXHIBIT B

SUMMARY OF ESTIMATED IMPACTS FOR THE REGIONAL PROTYTYPE SCENARIOS

PROTOTYPE SCENARIO		CHANGE IN REGIONAL WEEKDAY VMT		CHANGE IN REGIONAL WEEKDAY HIGHWAY EMISSIONS IN TONS†			CHANGE IN ANNUAL HIGHWAY FUEL CONSUMPTION IN MILLIONS OF GALLONS	PROGRAM COSTS IN 1976 DOLLARS (x1,000)	
ID No.	BRIEF TITLE*	AS PERCENT OF TOTAL VMT	AS PERCENT OF WORK TRIP VMT	HC	NO_X	CO		CAPITAL (ONE-TIME, IMPLEMENTATION)	INCREMENTAL OPERATING (PER YEAR)
11	Carpool/Vanpool Program, Medium Size City; Favorable Impacts	–1.5%	–5.0%	–1.0*	–0.6*	–15.0*	–2.6*	–	78
12	Carpool/Vanpool Program, Large City; Favorable Impacts	–1.5%	–5.0%	–8.3	–2.8	–83.4	–11.8	–	404
13	Reserved Bus/Pool Lanes, Ramp Metering, and Bus By-Pass Lanes on All Appropriate Freeways; Modest Impacts	–0.25%	–0.8%	–0.3	–0.5	+ 2.6	– 1.5	14,500/19,446	6,263
14	Reserved Bus/Pool Lanes, Ramp Metering, and Bus By-Pass Lanes on All Appropriate Freeways; Favorable Impacts	–0.44%	–1.5%	– 2.5	–0.4	–17.9	– 2.7	18,744/23,004	6,798
15	Reserved Median Lane for Express Buses on Appropriate Radial Arterials; Modest Impacts	–0.23%	–0.8%	+2.1	–0.4	+37.2	– 1.8	18,868/21,704	5,984
16	Reserved Median Lane for Express Buses on Appropriate Radial Arterials; Favorable Impacts	–0.38%	–1.3%	–0.7	–0.6	+ 5.8	– 2.9	18,868/21,704	5,984
17	Carpool/Vanpool Program and Freeway Reserved Lanes; Modest Impacts	–1.0%	–3.3%	– 2.4	–1.9	–29.1	– 7.2	9,804/14,664	5,408
18	Carpool/Vanpool Program and Freeway Reserved Lanes; Favorable Impacts	–1.9%	–6.3%	–10.5	–3.3	–81.1	–14.1	11,190/18,050	5,921
19	Carpool/Vanpool Program, Reserved Lanes, Ramp Metering, and Bus By Pass Lanes; Modest Impacts	–1.0%	–3.3%	– 4.5	–1.6	–29.8	– 7.3	14,580/19,440	5,957
20	Carpool/Vanpool Program, Reserved Lanes, Ramp Metering, and Bus By-Pass Lanes; Favorable Impacts	–1.9%	–6.5%	–10.9	–3.3	–83.9	–14.2	18,744/23,004	7,202

*All scenarios except #11 are for a "large" city (1,000,000 + SMSA population). Scenario 11 is set in a "medium size" city (500,000 - 1,000,000 SMSA population).

†Estimated at 75°F assuming uninterrupted traffic flow conditions.

large part related to the limited size of the peak period radially-oriented CBD travel market in most large urban areas. For example, home to work trips and VMT comprise approximately 20 percent and 30 percent of total weekday regional person trips and VMT, respectively. Travel survey data suggest that approximately 15 percent of home to work person trips are oriented to the CBD of large urban areas.

Scenarios 11 and 12, which involve major employer carpool and vanpool programs, are particularly cost-effective in reducing regional air pollution emissions.

Scenarios 13 through 17, which incorporate express bus service and reserved freeway or arterial lanes in multiple corridors, are less cost-effective than Scenario 12 in reducing HC emissions. The combination of carpool and vanpool programs with express bus service/reserved lane strategies in Scenarios 18 and 20 are estimated to result in larger reductions in HC emissions than Scenario 12 but for a significantly larger cost.

Considerations in Air Quality Analyses

The report illustrates the magnitude and type of air quality, emission, travel, fuel consumption, and cost impacts that could result from the implementation of selected TSM actions in settings similar to those described for the 10 localized and 10 regional scenarios. The reader should note that the impact estimates developed in the project are scenario-specific and great care must be taken in attempting to directly apply the results of this analysis to specific real-world circumstances.

The impacts presented in this report also reflect assumed "modest" and "favorable" travel impacts based on the findings of the literature review. The travel impact estimates are considered to be reasonable, particularly in light of the wide range in travel impacts which have been observed in demonstration projects. However, substantially different travel impacts could occur in a specific application, depending upon the characteristics of the project.

The application of TSM tactics such as pricing incentives/disincentives, auto restricted zones, area licensing, and parking pricing and supply controls in conjunction with the reserved lane, carpool, vanpool and related scenario tactics has not been examined in this report. Such tactics combined with those examined in this report offer considerable promise for achieving even more significant reductions in emissions.

Selection of TSM Actions for Analysis

The analysis of the prototype localized and regional scenarios demonstrates the need to clearly define the geographic scale of the air quality problems facing an urban area. The selection of tactics for analysis should be consistent with the scale of the area's air quality problems. Many tactics are particularly applicable to alleviating localized air quality problems while other tactics, such as carpool and vanpool programs, are appropriate for addressing regional air quality problems.

For example, the results of the regional scenarios illustrate that the application of the HOV freeway or arterial lanes on multiple radial highways was substantially less effective in reducing regional air pollution emissions than the carpool/vanpool programs. However, these same strategies were considerably more effective in reducing CO concentrations adjacent to applicable freeways and arterials.

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I. INTRODUCTION

OBJECTIVE

This report evaluates the use and cost-effectiveness of alternative short-range reserved lane, transit, carpool, and vanpool programs as techniques for improving air quality in urban areas. The report has been prepared in accordance with Section 108(f) of the Clean Air Act, as amended August 1977. It is intended to assist elected officials, government administrators, transportation planners, and transportation system operators in developing transportation measures for the State Implementation Plan and integrating transportation system management (TSM) and air quality planning programs as required by the Federal Highway Administration, the Urban Mass Transportation Administration and the Environmental Protection Agency, respectively.[1,2]

The specific types of short-range transportation programs examined in this report include:

- priority treatment for high occupancy vehicles on freeways and arterials;
- areawide carpool and vanpool programs; and
- transit fare reductions and service improvements.

The application of other transportation measures such as inspection and maintenance programs for vehicles, parking controls, traffic operations, and pricing are not covered in this project, but will be the subject of future study.[3]

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[1] Federal Highway Administration and Urban Mass Transportation Administration, Transportation Improvement Program. Part 450; Federal Register, Vol. 40, No. 181, September 17, 1975.

[2] Environmental Protection Agency. Transportation Planning Guidelines. Draft Guidelines, November 28, 1977.

[3] Section 108(f) of the Clean Air Act, as amended August 1977 requires EPA to publish information reports regarding processes, procedures, and methods to reduce or control each transportation related pollutant. Reports will be prepared on a wide range of actions (e.g., traffic flow improvements, on-street parking controls, road user charges, and road use restrictions).

The report is intended to provide information to assist urban areas covered by EPA's Transportation Planning Guidelines in:

- assessing the applicability and potential of the three classes of programs described above for improving localized and regional air quality;
- estimating and evaluating the cost-effectiveness of such programs and their related travel, energy consumption, cost, and economic impacts; and
- identifying key factors (e.g., meteorological conditions, vehicle type distributions, and vehicle operating speeds) likely to affect air quality and air pollution emissions.

This information report addresses the above issues at a sketch planning scale of analysis. More detailed transportation and air quality analyses will be required to adequately address localized and regional air quality problems within specific urban areas.

BACKGROUND

Problem

Virtually all urban areas of more than 200,000 population in the nation currently do not meet National Ambient Air Quality Standards (NAAQS) for photochemical oxidants (O_x). Many of these areas also exceed National Ambient Air Quality Standards for carbon monoxide (CO). Vehicluar travel within these urban areas is a major source of both pollutants.

As illustrated in Exhibit 1, transportation-related air quality problems are of two general types: localized and regional.

Localized transportation-related air quality problems generally result in CO concentrations exceeding either the one hour or more likely, the eight hour CO air quality standard. Factors contributing to this problem include high vehicular traffic volumes occurring under congested traffic conditions frequently found in densely developed portions of urban areas.

Regional transportation-related air quality problems are typically a result of vehicular and stationary source hydrocarbon (HC) and nitrogen oxide (NO_x) emissions chemically reacting in the atmosphere to produce oxidant

EXHIBIT 1
ILLUSTRATIVE TRANSPORTATION-RELATED AIR POLLUTION PROBLEMS

TYPE OF PROBLEM	POLLUTANT	AIR QUALITY STANDARD	TYPICAL IMPACT AREA	SELECTED TRAVEL FACTORS CONTRIBUTING TO PROBLEM
LOCALIZED	CARBON MONOXIDE	8 HOUR 10,000 μgm/meter^3 (9 PPM) 1 HOUR 40,000 μgm/meter^3 (35 PPM)	• INTERSECTIONS • LOCATIONS ADJACENT TO FREEWAYS AND ARTERIALS	• HIGH VEHICULAR TRAFFIC VOLUMES • STOP AND GO TRAFFIC FLOWS (e.g. IDLING)
REGIONAL	PHOTOCHEMICAL OXIDANT	1 HOUR 160 μgm/meter^3 (0.08 PPM)	OVERALL URBAN AREA (BASED ON OXIDANT CONCENTRATIONS MEASURED AT SPECIFIC LOCATIONS)	• HIGH VEHICULAR TRAFFIC VOLUMES • HIGH SPEEDS

a/STANDARD NOT TO BE EXCEEDED MORE THAN ONCE PER YEAR.

pollutants. The chemical reactions producing oxidants are complex and depend upon many factors such as prevailing meteorological conditions and the topographic, land use, and industrial characteristics of an urban area.

The distinction between the CO and oxidant pollutants is important in that different TSM actions are generally required to effectively address localized as opposed to regional air quality problems. For example, a TSM program to implement a reserved lane for carpools and buses on a single freeway may reduce CO emissions in the vicinity of the freeway, but is unlikely to have a noticeable impact on regional oxidant emissions. Similarly, a regional carpool program may contribute to a reduction in hydrocarbon and nitrogen oxide emissions (and, indirectly, oxidant concentrations), but generally is unlikely to have any measurable impact on localized CO concentrations.

Legislative Requirements

With the passage of the Clean Air Act of 1970, a comprehensive national program was undertaken to improve air quality, particularly in urban areas. EPA promulgated air quality standards and undertook programs (1) to reduce vehicle-related air pollutants through vehicle emission standards, emission controls (e.g., retrofits), and inspection/maintenance programs, and (2) to implement transportation policies, regulations, and projects to further reduce transportation-related emissions to meet air quality standards.

In accordance with the Clean Air Act of 1970, transportation control plans were developed by state, regional, and local agencies as well as by EPA for those urban areas which did not meet air quality standards. Unfortunately, the transportation control plans were frequently developed on an ad-hoc basis under very restricted time schedules, and did not have clearly defined agency responsibilities and/or funding sources for ultimate implementation of actions in the control plan. Consequently, the control plans generally had limited effect on improving air quality in applicable urban areas.

Several important legislative and procedural developments have occurred since 1975 which are intended to remedy many of the important limitations of the initial transportation control plans.

In September 1975, the Federal Highway Administration (FHWA) and the Urban Mass Transportation Administration (UMTA) jointly issued regulations requiring that urban areas (through a designated metropolitan planning organization - MPO) develop both short-range and long-range transportation plans to improve the transportation systems within urban areas.

The short-range plan is referred to as the Transportation System Management Element (TSME). The TSME is intended to identify low-cost, short-range transportation improvements, services, and programs which can be implemented within a five-year period. Projects must be included in the TSME in order to qualify for U.S. DOT funding. An important aspect is that the planning program must be coordinated with air quality planning within the urban area and must consider the air quality impacts of proposed transportation actions. Similarly, the long-range element is to account for the air quality effects of long-range transportation improvements.

The Clean Air Act, as amended August 1977 include the following major provisions for reducing travel-related emissions and meeting air quality standards in urban areas:

- States must prepare State Implementation Plans (SIP) by January 1, 1979. The SIP are to contain transportation plans for CO and oxidant nonattainment urban areas. The plans are to achieve CO and oxidant standards as expeditiously practicable, but no later than 1982 unless the implementation of all reasonable measures will not attain the NAAQS. Under such circumstance, an extension to 1987 may be granted.

- $75 million is authorized (to be appropriated) by the Act to develop plans for nonattainment areas. This authorization is to support transportation-related planning activities.

- Transportation planning guidelines are being issued by EPA to promote agency interaction at all levels of government, involvement of local elected officials, effective public participation, and integration with the ongoing US DOT planning processes. The guidelines provide for annual EPA review and approval of the transportation planning process and progress in meeting air quality standards.

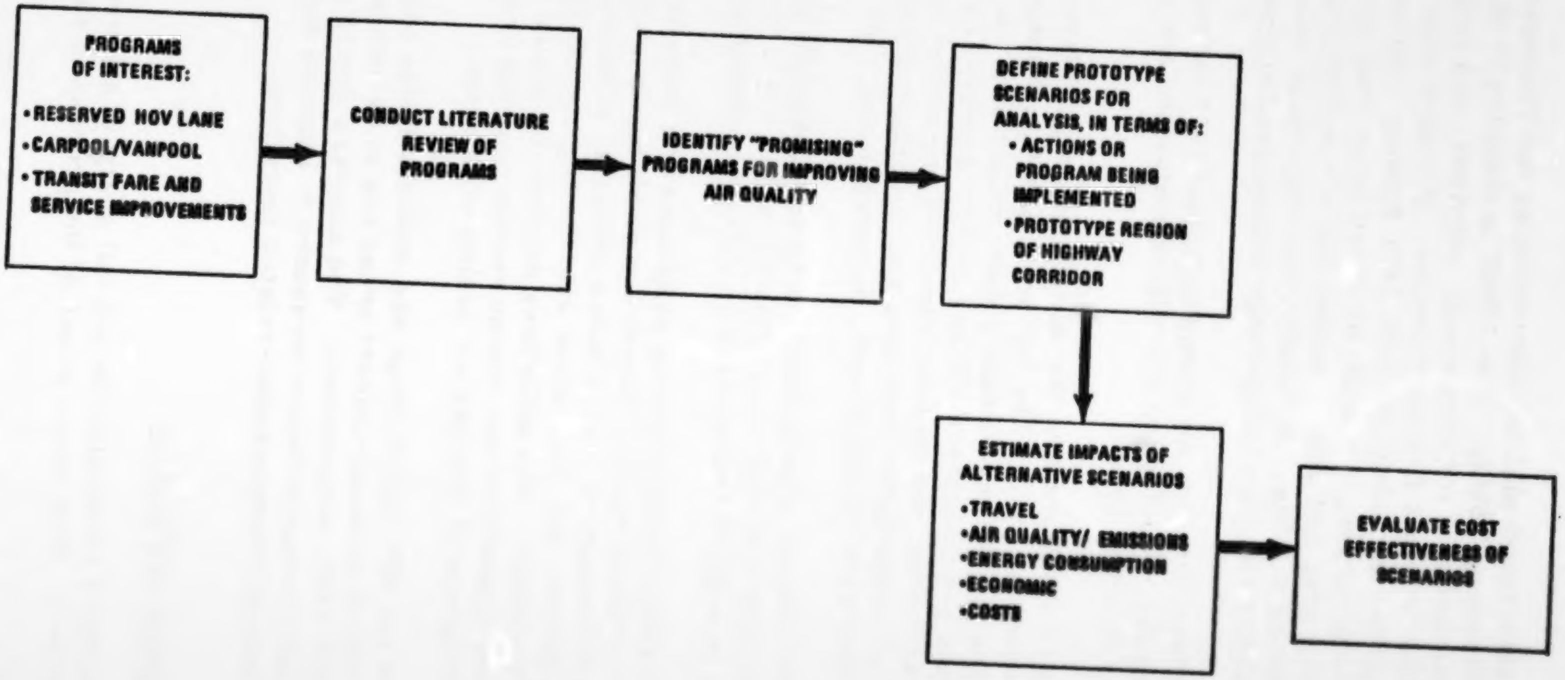
- In the SIP, short-range and medium-range analyses of air quality in nonattainment areas are to be conducted for 1982 and 1987, respectively. The analyses are to consider alternative transportation measures to improve air quality and reduce transportation-related emissions.

ANALYSIS APPROACH

Exhibit 2 illustrates the overall analysis and evaluation process used in the project. Each major phase of the process is summarized below.

EXHIBIT 2

GENERALIZED ANALYSIS AND EVALUATION FRAMEWORK


PROGRAMS OF INTEREST:
•RESERVED HOV LANE
•CARPOOL/VANPOOL
•TRANSIT FARE AND SERVICE IMPROVEMENTS
CONDUCT LITERATURE REVIEW OF PROGRAMS
IDENTIFY "PROMISING" PROGRAMS FOR IMPROVING AIR QUALITY
DEFINE PROTOTYPE SCENARIOS FOR ANALYSIS, IN TERMS OF:
• ACTIONS OR PROGRAM BEING IMPLEMENTED
•PROTOTYPE REGION OF HIGHWAY CORRIDOR
ESTIMATE IMPACTS OF ALTERNATIVE SCENARIOS
•TRAVEL
•AIR QUALITY/ EMISSIONS
•ENERGY CONSUMPTION
•ECONOMIC
•COSTS
EVALUATE COST EFFECTIVENESS OF SCENARIOS

Literature Review

A comprehensive literature review was conducted to identify and summarize the travel, air quality, cost and related impacts of the freeway and arterial priority treatment programs, areawide carpool and vanpool programs, and transit fare reduction and service improvements programs. The literature review included relevant demonstration and operational projects and analytical/model-based evaluations of the programs of interest. The findings of the review were used (1) to identify those transportation programs having the potential to improve localized and/or regional air quality; and (2) to provide the basic inputs for estimating the travel, air quality/emission, cost and related impacts of the 20 transportation programs selected for analysis and evaluation in this project.

The findings of the literature review are presented in Section II. An annotated bibliography documenting references examined in the project was prepared for distribution as part of the project.[1]

"Promising" Transportation Programs

Transportation programs within the scope of this project which demonstrated potential for cost-effectively improving either localized or regional air quality were selected for detailed analysis and evaluation based on the findings of the literature assessment.

In order to quantitatively assess the air quality and related impacts of interest, 20 scenarios were developed to evaluate the "promising" transportation measures. A prototype scenario includes the definition of the following:

- the program (individual action or combination of actions) to be analyzed;
- the physical and operating characteristics of the program (e.g., number of lanes, hours of operation);
- the geographic area in which the program is to be implemented (e.g., radial corridor, areawide); and
- "existing" travel and meteorological characteristics for the geographic area of interest.

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[1] Peat, Marwick, Mitchell & Co., Transit Improvement, Preferential Lane and Carpool Programs: An Annotated Bibliography of Demonstration and Analytical Experience (Prepared for EPA, Office of Transportation and Land Use Policy), November 1977.

The scenarios were defined to represent "real-world" circumstances in which the alternative programs of interest are typically implemented. The use of scenarios, rather than actual projects which have been implemented, provides a more consistent basis for comparing the cost-effectiveness and the magnitudes and characteristics of the associated impacts for the programs of interest.

Scenarios were formulated to analyze alternative programs to improve both localized and regional air quality. The transportation programs receiving detailed analysis and evaluation are summarized in Section III.

Scenario Impacts

A variety of data sources and analysis procedures were used to estimate the travel, emission, air quality, energy consumption, economic and cost impacts for the programs and settings (i.e., scenarios) analyzed. Travel impacts for each scenario were estimated based on the findings of the literature review, supplemented as required by assumptions of the project team. Traditional urban transportation planning models were not used in the analysis because of the difficulty of representing the programs of interest using such procedures and because of the coarseness of the outputs of such models in analyzing strategies for reducing localized CO concentrations.

Emphasis was placed on developing "reasonable" travel impact estimates for each prototype based primarily on before-and-after travel impact data found in the literature. This approach is consistent with the substantial range of observed travel impacts associated with similar transportation programs implemented throughout the nation.

A modified version of the EPA HIWAY Model and the current EPA mobile source emission factors were used to estimate CO concentrations for localized programs and tons of emissions by pollutant for regional programs, respectively.[1,2] The energy consumption, economic, and capital and operating cost impacts for each prototype were estimated using published consumption rates, unit costs, and other applicable data compiled in the literature review.

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[1] Environmental Protection Agency, User's Guide For HIWAY, A Highway Air Pollution Model. EPA-650/4-74-008, February 1975.

[2] Environmental Protection Agency, Mobile Source Emission Factors. January 1978.

A summary of the major data sources, analytical assumptions, and procedures used to estimate non-cost impacts for each prototype scenario is presented in Appendix A. Section III summarizes the travel, air quality/emission, energy consumption, economic, and cost impacts for each scenario.

Evaluation of Scenario Impacts

Section IV evaluates the impacts of promising transportation programs within the context of 20 prototype scenarios. The section analyzes the cost-effectiveness of the alternative programs in promoting improved air quality and reducing vehicular emissions in urban areas. The relative magnitude and characteristics of the impacts for the localized and regional programs are compared. An important element of this section is a discussion of factors, such as prevailing meteorological conditions, stationary source emissions, and future automobile emission rates, which may affect the transferability of the project's findings to specific urban areas.

II. PERFORMANCE AND POTENTIAL OF RESERVED LANE, CARPOOLING/VANPOOLING, AND TRANSIT SERVICE PROGRAMS

This section summarizes the travel and cost impacts of the following programs of interest:

- freeway priority treatment for high occupancy vehicles;
- arterial priority treatment for high occupancy vehicles;
- areawide carpool and vanpool programs; and
- transit fare reductions and service improvement programs.

The findings presented in this section are based on a comprehensive literature review of both operational and proposed programs of the above types.

Based on these findings, programs which have the potential for cost-effectively reducing emissions and improving air quality were selected.

LITERATURE REVIEW FINDINGS--TSM STRATEGY IMPACTS AND POTENTIAL

Tabular Summary of Findings

Exhibits 3 through 6 present the travel impacts and capital and operating costs for the four types of programs noted above. For each of the programs of interest, strategies of similar physical or operating characteristics are grouped together to illustrate the variability in travel impacts and costs, and to summarize the voluminous findings of the literature review at a level of detail that facilitates selection of individual programs and combinations of programs for detailed analysis and evaluation in this project.

The format of Exhibits 3 through 6 varies to accommodate the differences in the descriptive characteristics and travel impacts most relevant to each program.

In using the tables of Exhibits 3 through 6, the following should be kept in mind:

- In a number of cases, the data or information presented in various rows of a column may vary in format and/or content. Unfortunately, this is unavoidable because of the diversity of information reported in the available sources and the lack of uniform documentation in the literature.

- Blanks in the table identify data which were either not provided by available sources or which were considered to be too ambiguous or unreliable to be usefully reported. Through these blanks and the "level of documentation" ratings discussed in the footnote to the tables, the summary tables graphically highlight the data deficiencies.

- In a number of cases, information for a strategy supported by data from several sources will be attributed explicitly to a single source. This alerts the reader to data which are based on only one experience or model estimate, and which may not be representative of all the experiences cited for the strategy.

Freeway Priority Treatment for High Occupancy Vehicles

Documentation of Past Experience

Relative to the other major categories of strategy, experiences with priority treatment of high occupancy vehicles on freeways were fairly well documented (see Exhibit 3). The considerable interest and investment in these strategies and programs prompted substantial demonstration monitoring and evaluation efforts in many cases. This was particularly true of the projects involving the expenditure of large sums in the construction of new priority facilities, such as the Shirley Highway high occupancy vehicle lanes.[1] However, even for the relatively well documented freeway priority strategies, the extent, reliability, and transferability of the available information are not entirely satisfactory. The primary reasons for this are that

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[1] Although such programs are long-range, capital intensive projects technically outside the scope of this report, they were included in the literature review and summary tables because of their similarity to within-scope reserved lane approaches and because of the wealth of potentially transferable data available. However, in evaluating these data, one must be careful to account for the significant differences between reservation of existing lanes and the construction of separate new priority facilities.

EXHIBIT 3

FREEWAY PRIORITY TR
HIGH OCCUPANCY

	STRATEGY	STRATEGY OPTION/ APPLICATION LIMITATIONS	DEMONSTRATION OR MODEL ESTIMATE DATA SOURCES*	RANGE OF REPORTED PROJECT CHARACTERISICS								
							VEHICLE VOLUME		TRAVEL TIME			
				FACILITY	DAILY HOURS OF OPERATION	COSTS (000)	BASE	% △	BASE	% △	PREFERRED LANE TIME ADVANTAGE	
A	Contra-Flow Bus Only Lane on Freeway		. Long Island Expressway, N.Y.C. (VG) . I-495 Approach to Lincoln Tunnel (VG) . South East Expressway, Boston (VG)	6-Lane Divided Freeway; 2.2-8.4 Miles in Length	2-3.5 Hour A.M. Peak	Implementation: $40-917 Operation: Year Year	Auto: 9,500-10,000 Bus: 57-826	-3.6 to +10 +14 to +44 (+25)#	20-25 Min. (2.9-10 Min. Per Mile)	Auto -20 Bus: -22 to -75 (-40)	-10 to +15 Min. (+7.5 Min.)	2,15
B	Normal Flow Freeway Lane Reserved for Buses and Carpools (3+) in Each Direction and Expanded Express Bus Service		. I-93, Boston (G) . Moanalua Freeway, Honolulu (F) . Santa Monica Freeway, Los Angeles (VG) . Banfield Freeway, Portland, Oregon (G)	8-Lane Divided Freeway; 1.4-12.6 Miles in Length	A.M. Peak; A.M./P.M. Peaks; and 24 Hours	Implementation: $35-100	Auto: 4 Hour Direction Peaks: A.M. East 28,600 P.M. East 27,650 A.M. West 24,450 P.M. West 28,250 (Santa Monica Only) Bus: 8-15 Peak Period	+8 to -28 (-16) +100 to +113	20-21 Min. (Data for Santa Monica Only)	Prefer.: -23 to -28 (-25) Non-Prefer.: -5 to -20 (Santa Monica)	+1.5 to +3.5 Min. (Data From Santa Monica Only)	400 A To 1, and P.
C	Metered Freeway Access Ramps with Bus By-Pass Lane; Expanded Express Bus Service and Park-and-Rid Lots		. I-35 Freeway Ramps, Minneapolis (E)	9 Ramps to 6/8 Lane Freeway	2.5 Hour A.M. Peak 3 Hour P.M. Peak	Implementation: $84 Per Ramp**	Facility: 23,700 Daily Parallel Arterials: 12,800 Daily Total Corridor: 36,500	+1.7 +3.1 +2.2	29.4 Min.	-26	+2 to +2.5 Min.	Express 2,100; Local (P 22,300 Total:
D	Exclusive Bus Access Ramp Serving CBD Loop (Express Buses also Added)		. I-5 Freeway Ramp, Seattle (G)	1 Reversible Ramp to 6/8 Lane Freeway	24 Hours	Implementation: $15 (Does not Include Construction)	Daily Freeway Total: 130,000		50 Min.	-20	5-10 Min.	A.M.: P.M.:
E	Metered Freeway Ramps With By-Pass For Buses and Carpools (2+)		. 5 Freeways in Los Angeles (F)	10-24 Ramps on 5 Different Freeways	A.M. and P.M. Peaks	NA	Auto: N.A. Carpool: 825 Bus: N.A.	+100			+2.5 Min. Per Ramp Queue	
F	Priority No-Toll Lanes for Buses and Carpools at Toll Plaza		. San Francisco-Oakland Bay Bridge (G)	0.5 Mile in Length: 1 Bus Lane; 2 Pool Lanes	A.M. and P.M. Peaks Prior to 1976; 6:00 A.M.-6:00 P.M. in 1976	Implementation: $398 Operation: $28 Per Year	Auto: N.A. Carpool: 1,025-1,640 Peak Bus: 500 Peak	+80 to +100 Negligible			+5 Min.	20,
G	Specially Constructed Exclusive Lanes in Each Direction for Buses and Carpools (3+/2+); Expanded Express Bus Service		. I-95, Miami (F)	Freeway Lanes in Median, 7.5 Miles in Length 1 Exclusive Ramp	4-Hour A.M. and P.M. Peaks. Otherwise, Open to All Traffic	Implementation: $18,500					Up to 15 Min.	
H	Specially Constructed Exclusive Reversible Lanes for Buses and Carpools (3+); Expanded Express Bus Service		. Shirley Highway, I-95/395, Virginia (E)	2 Separated, Reversible Freeway Lanes; 11 Miles in Length	3 Hour A.M. Peak 4 Hour P.M. Peak	Implementation: $43,000 Plus $4,000 in New Buses Operation: $10-15 Per Year (excluding bus operating cost)	Facility Only Bus:** 109 (3/71) Auto: N.A. Corridor Survey Auto: 1970 – 40,000 1971 – 36,000 1972 – 37,100 1973 – 40,400 1974†† – 38,600 Bus:** 1970 – 302 1971 – 359 1972 – 408 1973 – 447 1974†† – 508 ** 49 Passengers/Bus †† Carpools Allowed To Use Facility Starting This Year	+158 (By 1975) +65 -10 +3.1 +8.9 -4.4 +18.9 +13.6 +9.6 +13.6			A.M.: 13 Min. P.M.: 20 Min.	For E 1970 1971 1972 1973- 1974
I	Specially Constructed Exclusive Lane in Each Direction for Buses Only		. San Bernardino Freeway-Busway, Los Angeles (E)	2 Lane Exclusive Roadway in Median and Along Side of 8-Lane Freeway; 11.2 Miles in Length., with Off-Line Stations.	24 Hours	Implementation: $57,000 $60,000	140,000-170,000 Per Day, Both Directions				16-22 Min.	Daily: Peak P

* Level of Documentation: E - Excellent VG - Very Good G - Good F - Fair P - Poor

( ) Best Judgmental Estimates Appear in Parentheses

* *Excludes costs for bus acquisition, ramp metering and other improvements.

A

EXHIBIT 3

EWAY PRIORITY TREATMENT FOR HIGH OCCUPANCY VEHICLES

BASE CONDITIONS AND TRAVEL IMPACTS													
TRAVEL TIME		TRANSIT RIDERSHIP				MODAL SPLIT			AUTO OCCUPANCY		AVERAGE SPEED		
% Δ	PREFERRED LANE TIME ADVANTAGE	BASE	% Δ	SOURCE OF "AFTER" RIDERSHIP	TIME ELASTICITY OF RIDERSHIP	BASE	ABS. % Δ	REL. % Δ	BASE	Δ	BEFORE	AFTER	% Δ
. −20 : −22 to (−40)	−10 to +15 Min. (+7.5 Min.)	2,152 34,692 Daily	+14 to +44 (+25)	Same Bus: 81% Other Bus, Transit: 9-12% Auto Driver: 2-8% Auto Pass.: 2-3% New Trip: 2-3% (Based Primarily on I-495 Data. Very Limited Potential For Shift From Auto Since 85% of Trips to Manhattan are by Transit)	−.25 to −.30	Auto: 86.2% Bus: 13.8% (Data From Boston Only)	−2.5 +2.5	−2.9 +18	1.44 1.6	−.05 to −.06	6 21	Auto: N.A. Bus: 30-40	+45 to +560 (+250)
: −23 −20 (−25) -Prefer.: −5 −20 (Santa nica)	+1.5 to +3.5 Min. (Data From Santa Monica Only)	480 A.M. Peak Up To 1,260 For A.M. and P.M. Peaks	+87 to +202 (+110)		−3 to −8	Auto (1,2 Pass.): 93.6% Pool: 5.3% Bus: 1.1%	−10.5 +8.5 +2	−11.2 +160 +182	1.23 to 1.35	+.09 to +.13			
	+2 to +2.5 Min.	Express (On Facility): 2,100: Local (Parallel Arterials): 22,300 Total: 24,400	+238 −8.5 +12.7		For Total Express Bus −9, Express Bus Excluding Bus Diversion: −4.5	For Entire Corridor: Bus: 33% Auto Driver: 48% Auto Pass.: 19%	+6 −5 −1	+18 −10 −5	Frwy.: 1.32 Art.: 1.33 Total: 1.32	−.04 −.02 −.02	Freeway: 34	45	+29
	5-10 Min.	A.M.: 3,400 P.M.: 3,000	+194 to +233 (Incl. Impact of New Express Buses)										
	+2.5 Min. Per Ramp Queue			50% of New Pools on Freeway From Other Routes 50% of Pools Newly Formed					1.24	+.09			
	+5 Min.	20,000	Negligible	200 Bus Riders Switched To Carpool					1.33	+.10			
	Up to 15 Min.												
	A.M.: 13 Min. P.M.: 20 Min.	For Entire Corridor: 1970 14,800 1971 17,600 1972 20,000 1973 21,900 1974 24,900		Among Those Not Captive To Bus:* Now: Bus % Carpool % Prior Auto Driver: 41 39 Auto Pass.: 12 30 Bus: 38 25 Other: 9 6 * 1 Year After Carpools Allowed		Corridor % Transit: 1970 21 1971 27 1972 28 1973 29 1974 31			Corridor: 1970 1.39 1971 1.33 1972 1.30 1973 1.32 1974 1.46 (Carpools Added in 1974) Facility: 1971 1.35				
	16-22 Min.	Daily: 1,800 Peak Period: 1,000	+733 +800	Always Bus: 10% Auto Drive Alone: 58% Auto Drive With Pass.: 7% Auto Pass.: 11% Alternate Carpool Driver: 11% Non-Busway Bus: 2%						Negligible	30-35	Bus: 50-55 Non-Pref.: Better Than 30-35	+55 to +60

B

characteristics of specific demonstration projects varied significantly and the data reported were frequently incomplete, ambiguous, or reported in a form that made comparison difficult. Finally, data were primarily available for larger urban areas, so the impacts of these programs on smaller areas is uncertain.

Assessment of Strategy Impacts and Potential

Freeway priority strategies can have significant localized (CO) air quality impacts and reduce vehicle volumes in the peak period by 3 to 10 percent. Freeway priority strategies are especially effective when applied as part of strategies favoring high occupancy vehicles in a corridor and discouraging the use of automobiles through disincentives (e.g., parking charges and restraints, etc.). Other factors which can promote the effectiveness of such strategies include a soundly designed enforcement program, improved transit service and marketing programs, and a public information program to inform affected travelers of the benefits and costs of reserving an existing freeway lane for HOV's.

When these strategies are implemented to improve localized CO air quality, great care in planning and implementation is necessary. Diversions to and from parallel roads and the possibility of creating counterproductive increases in congestion on non-priority lanes must be considered in designing these strategies. Even when the travel time for high occupancy vehicles is reduced substantially by the strategy, regional air quality and VMT impacts of freeway priority strategies are not very significant. The reasons for this are:

- CBD oriented peak work travel, that travel primarily susceptible to these strategies, is only a fraction of total travel; and
- despite the travel time reduction, overall door-to-door travel time may still be shorter by single occupant car than by either bus or carpool.

As with any of the strategies, the freeway priority strategies can make a useful contribution to regional air quality as part of a comprehensive package of strategies whose total impact is significant.

Among the freeway strategies treated in the strategy summary tables, the following seem to have the greatest potential in terms of travel impact:

- with-flow freeway lanes reserved for buses and carpools;
- contraflow bus-only lanes on freeways; and

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- metered freeway access ramps with bus by-pass lanes.

Arterial Priority Treatment for High Occupancy Vehicles

Documentation of Past Experience

In most cases, the available documentation for strategies involving the priority treatment of high occupancy vehicles on arterials was unsatisfactory (see Exhibit 4) for the same reasons as cited for the freeway priority strategies. Adequate before-and-after data for critical travel variables were unavailable. Project monitoring was frequently qualitative and project evaluation activities, when present at all, were not focused on overall travel and air quality improvement impacts. Finally, transit ridership data are not usually available on a basis which would permit link-specific evaluation of projects confined to specific urban arterial segments.

Assessment of Strategy Impacts and Potential

For the reasons cited above, it is difficult to make reliable quantitative assessments of the travel and air quality impact performance of the specific priority arterial strategies. Generally though, arterial strategies have potential for improving localized CO air quality, especially in congested downtown areas which are more directly served by arterials than by freeways.

Overall, the potential which arterial strategies offer for improving localized CO air quality seems to be less than the potential offered by freeway strategies for the following reasons:

- the amount of travel affected by arterial strategies tends to be smaller on a project-by-project basis--although this is partially offset by the greater number of arterial streets on which improvements might be made;

- traffic signal and other delays encountered on arterials (but not freeways) tend to dilute the travel time savings achieved by preferential treatment of high occupancy vehicles;

- turning vehicles may traverse the priority lane--thereby inhibiting its effectiveness;

- lane restrictions on arterials are more difficult to enforce, also tending to dilute the travel time advantages for high occupancy vehicles; and

EXHIBIT 4

ARTERIAL PRIORITY TRE
HIGH OCCUPANCY V

STRATEGY	STRATEGY OPTION/ APPLICATION LIMITATIONS	DEMONSTRATION OR MODEL ESTIMATE DATA SOURCES*	RANGE OF REPORTED PROJECT CHARACTERISTICS			VEHICLE VOLUME		TRAVEL TIME		
			FACILITY	DAILY HOURS OF OPERATION	COSTS (000)	BASE	% △	BASE	% △	PREFER TIME ADV
A. Normal Flow Curb Lane on Arterial Reserved for Buses	1. Single Street Over A Mile in Length	. Arlington Blvd., Arlington, Virginia (G) . Wilson Blvd., Arlington, Virginia (P) . York Road, Baltimore (G) . 11 NYC Arterials (G) . Main St., Rochester, N.Y. (F)	Curb Lane Reserved for Buses and Right Turns. 1.5-6.5 Miles in Length	A.M. and P.M. Peaks. For Main St., 24 Hours	Implementation: From Nominal to $1,300 for 4.5 Miles	Buses: From 36 in Peak Period Up to 100-150 in Peak Hour		Auto: Bus:	+2 to +9 -42 to +11 (-15 to -20 When Strategy "Works") #	
	2. Single Street Of A Mile or Less in Length	. Several Parallel CBD Streets in Baltimore (G) . 19th St., North Birmingham, Al. (F) . Church and Main Sts., Buffalo, N.Y. (F) . Elm and Commerce Sts., Dallas (G) . 16th and 17th Sts., Denver (F) . 4th Ave., Nashville (F) . Washington and Weybosset Sts., Providence, R.I. (F) . Geary-O'Farrell, Sutter-Post Sts., San Francisco (F) . Market St., Newark, N.J. (F) . Market St., Philadelphia, Pa. (G) . Ben Franklin Bridge, Philadelphia (F)	Curb Lane Reserved for Buses, Right Turns. 3 Blocks up to 1 Mile in Length	A.M. and P.M. Peaks. 24 Hours for Market St. in Phila. and P.M. Peak Only for Market St., Newark	Nominal	Buses: From 55-65 in Peak Period up to 120-160 in Peak Hour		Auto: Bus:	N.A. -10 to -20 (55 to 140 sec. Improvement per Mile)	
	3. Substantial Number of Closely Located Downtown Streets	. 11 CBD Streets in Baltimore (G) . 18 Downtown Streets in Washington, D.C. (G)	Curb Lane Reserved for Buses, Right Turns. From 11 Streets of 3-18 Blocks Each (Total Approx. 5 Miles) to 27 Lanes on 18 Streets (Total of 26 Miles).	A.M. and P.M. Peaks on All Except 2 D.C. Streets, Which Are 24 Hours	Nominal	Buses: For D.C., a Total of 3,812 Bus Trips for All Lanes on All Streets During Period of Operation		Auto: Bus:	-3 in D.C. -17 to -21 in Baltimore, -35 in D.C.	
B. Reserve One Normal Flow Lane for Buses and One Lane for Carpools	For All Freeways and Arterials with 3 or More Lanes in the Peak Direction	. Model Estimates for 1977 for Washington, D.C. – Based only On Work Trips	All 3+ Peak Lane Freeways and Arterials	A.M. and P.M. Peaks		Approximately 1.3-1.4 Million Work Trips Affected	-2.01 (trips, not vehicles)			
C. Contra-Flow Bus Lane on One-Way Arterial		. University Ave., Madison, Wisc. (G) . Ponce De Leon and Fernandez Juncos, San Juan, P.R. (G) . Spring St., Los Angeles (F)	One Way Arterial (Usually 4 Lanes) of 0.9-10.8 Miles in Length with Contra-Flow Lane for Buses. San Juan Example Is A Couplet.	24 Hours	Implementation: $50 -$100 ($4 -$56 per Contra-Flow Lane-Mile)	Buses: 23-256 Peak Hour; 70-1,400 Daily		12.4-80 Minutes (5.06-8.27 Minutes per Mile)	-37.5 (For University Ave., Up to 6 Min. Saving for Bus Over 0.9 Mile)	
D. Contra-Flow Bus Lane On Two-Way Arterial		. Washington St. and Wacker Drive, Chicago (P) . Market St., Harrisburg (P) . Kalakaua and Kalanianole Sts., Honolulu (F) . College Ave., Indianapolis (F) . Marquett and 2nd Ave., Minneapolis (P) . Alamo Plaza, San Antonio (F)	Two Way Arterial Segments of 0.3-2.9 Miles in Length	24 Hours; Only A.M. Peak in Honolulu	Implementation: From Nominal to $30 for 13 Blocks (Approx. $45 per Mile). Operation: From Nominal to $2 per Year	Buses: 10-108 During Peak Hour			-2 Min. For 0.25 Mile Segment – Not Necessarily Representative	
E. Contra-Flow Bus Lane and Bus Signal Preemption Combination on Arterial		. 3rd St., Louisville, Kentucky (G)	Contra-Flow Bus Lane on 2 Mile Section of Arterial with Bus Preemption at 8 Signals	A.M. and P.M. Peaks	Implementation: $10 7			40.5-43.5 Minutes Over Routes 7.2-9.1 Miles In Length Which Include 2-Mile Contra-Flow Segment.	Bus: -13 to -27 (-25) # Auto: None	Auto Still Faster Th
F. Contra-Flow Bus Lane and Normal Flow Carpool (2+) Lane on Arterial		. South Dixie Highway, Miami (VG)	4-6 Lane Arterial of 5.5 Miles with Signalized Intersections	2 Hour A.M. and P.M Peaks	Implementation: $626 Operation: $437 per Year (excluding Bus Operating Subsidies)	Auto: 14,674 Peak Periods Carpool: 2,641 Bus: 10 Daily	-2.3 +52. +500.	18.2 Min.	+7.7 -33 -50	— 7.4 Min. 10.6 Min.

* Level of Documentation: E - Excellent VG - Very Good G - Good F - Fair P - Poor
#( ) - Best Judgmental Estimates Appear in Parentheses

A

EXHIBIT 4

RIAL PRIORITY TREATMENT FOR
IGH OCCUPANCY VEHICLES

BASE CONDITIONS AND TRAVEL IMPACTS													
TRAVEL TIME		TRANSIT RIDERSHIP				MODAL SPLIT			AUTO OCCUPANCY		AVERAGE SPEED		
% ∆	PREFERRED LANE TIME ADVANTAGE	BASE	% ∆	SOURCE OF "AFTER" RIDERSHIP	TIME ELASTICITY OF RIDERSHIP	BASE	ABS. % ∆	REL. % ∆	BASE	∆	BEFORE	AFTER	% ∆
+2 to +9 −42 to +11 (−15 to −20 When Strategy "Works") =			0% to +10% (0%)										
N.A. −10 to −20 (55 to 140 sec. Improvement per Mile)			Nominal or Not Significant When Reported										
−3 in D.C. −17 to −21 in Baltimore, −35 in D.C.			No Significant Change in Baltimore										
		490,000	+1.13 (Work Trip Base)							+.02 (+1.77%)			
−37.5 (For University Ave., Up to 6 Min. Saving for Bus Over 0.9 Mile)													
−2 Min. For 0.25 Mile Segment – Not Necessarily Representative													
Bus: −13 to −27 (−25) ≠ Auto: None	Auto Still 4-20 Min. Faster Than Bus												
+7.7 −33. −50	— 7.4 Min. 10.6 Min.	365 Daily	+436	"After" Bus Riders: Prior Mode Solo Auto 65.1% Carpool 12.5% Bus 17.1% Bicycle 3.5% Other 2.8% "After" Carpool Members: Prior Mode Solo Auto 61% Carpool 27% Transit 5.5%	Bus: −8.72								

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EXHIBIT 4 (Continued)

STRATEGY	STRATEGY OPTION/ APPLICATION LIMITATIONS	DEMONSTRATION OR MODEL ESTIMATE DATA SOURCES*	RANGE OF REPORTED PROJECT CHARACTERISTICS							
						VEHICLE VOLUME		TRAVEL TIME		
			FACILITY	DAILY HOURS OF OPERATION	COSTS (000)	BASE	%Δ	BASE	%Δ	PREFERRED LANE TIME ADVANTAGE
G Median Lane on Arterial Reserved For Express Buses, with Special Signal Control; Expanded Express Bus Service	Four-Phase Implementation: 0 Before 1 Bus Signal Preemption, Buses in Mixed Flow 2 Reserved Lane for Buses 3 Add Signal Progression 4 Add Bus Preemption of Signals	. 7th Ave., Miami (VG)	Reserved Median Lane of 9.9 Mile Length on Major Arterial	3.5 Hour A.M. and P.M. Peak Periods	Implementation: $1,350 Operation: $28.8 per Year (excluding bus operating costs)	A.M. Peak				
						Phase 0				1 Min.
						Bus: 0*	–	26.3 Min.	–	
						Auto: 1,634	–	27.3 Min.	–	
						Phase 1				3.9 Min.
						Bus: 26	"New Service"	21.2 Min.	–19.4	
						Auto: 1,797	+10	25.1 Min.	–8.0	
						Phase 2				5.2 Min.
						Bus: 26	–	18.5 Min.	–12.7	
						Auto: 1,445	–19.6	23.7 Min.	–5.6	
						Phase 3				0.9 Min.
						Bus: 26	–	20.1 Min.	+8.6	
						Auto: 1,392	–3.7	21.0 Min.	–11.4	
						Phase 4			–	N.A.
						Bus: 26	–	N.A.		
						Auto: 1,392	–	22.4 Min.	+6.7 (Changes are with respect to previous phase.)	
						* Empty Buses Run to Measure Travel Time In This Phase				
H Median Lane on Arterial Reserved for Buses		. Various Streets in Chicago (F) . Canal St., New Orleans (F) . Various Streets in Pittsburgh (P) . Market St., Philadelphia (F)	Various City Streets from 400 Feet up to 0.7 Mile in Length. Specific Arterials from 3,500 Feet to 1.5 Miles.	24 Hours	Implementation: Usually N.A., $1,450 for Canal St. Operation: N.A.	Buses: Variable; up to 160 in Peak Hour. 55 in Peak Hour and 350-375 Daily Round Trip for Canal St.				1.5 Min. Saved by Buses in 3,500 Ft. on Market St. "Several" Minutes Saved in Chicago.
I Urban Street Set Aside for Buses Only		. 63rd and Halstead Streets, Chicago (F) . Nicollet Mall, Minneapolis (F) . East Side Bus Tunnel, Providence, R.I. (F)	Chicago: 900 Ft. and 1,320 Ft., 22 Ft. Wide Providence: 2,160 Ft. Tunnel, 17.5 Ft. Wide	24 Hours	Generally N.A.	Buses: 18-75 in Peak Hour				2-3 Min. for Providence
J Bus Preemption of Traffic Signals on Major City Streets		. North Central Expressway, Dallas (P) . 3rd Street and Others in Louisville (F) . 31 Downtown intersections and 450 Equipped Buses in Washington, D.C. (F)	8-42 Intersections Affected in Each City. Total Facility Length of 12 Miles and 3 Miles For Dallas and Louisville, Respecitvely.	A.M. and P.M. Peaks	Implementation: $563,000 For Dallas $10,500 For Louisville. Operation: $.5 per Transmitter. $.8 per Receiver/Intersection				–10 to –20	
K Lane Reserved for Carpools (2+) on Urban Streets		Lawrence and Larimer Streets, Denver (P)	Reserved Lanes, Varying up to 24 Blocks.	Peak Periods					"Nominal"	

* Level of Documentation: E - Excellent VG - Very Good G - Good F - Fair P - Poor
≠( ) - Best Judgmental Estimates Appear in Parentheses

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EXHIBIT 4 (Continued)

BASE CONDITIONS AND TRAVEL IMPACTS														
TRAVEL TIME			TRANSIT RIDERSHIP				MODAL SPLIT			AUTO OCCUPANCY		AVERAGE SPEED		
ASE	%Δ	PREFERRED LANE TIME ADVANTAGE	BASE	%Δ	SOURCE OF "AFTER" RIDERSHIP	TIME ELASTICITY OF RIDERSHIP	BASE	ABS. %Δ	REL. %Δ	BASE	Δ	BEFORE	AFTER	%Δ
	– –	1 Min.	0	–			0%	–	–	1.30	–	20		
	–19.4 –8.0	3.9 Min.	673	"New Service"			22.5%	"New Service"		1.29	–.01		27 23	+35 +15
	–12.7 –5.6	5.2 Min.	751	+11.6			28.9%	+6.4	+28.4	1.28	–.01		29 22	+7.4 –4.3
	+8.6 –11.4	0.9 Min.	735	–2.1			29.3%	+.4	+1.4	1.26	–.02		N.A. 25	N.A +14
	– +6.7 (Changes are with respect to previous phase.)	N.A	735	–			29.3%	–	–	1.26	–		N.A 23	N.A. –8.0 (Percent Changes Relative to Previous Phase)
		1.5 Min. Saved by Buses in 3,500 Ft. on Market St. "Several" Minutes Saved in Chicago.												
		2-3 Min. for Providence		+40 For Nicollet Mall (Includes Other Improvements)										
	–10 to –20													
	"Nominal"													

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- since there are frequently good substitute routes for affected arterials (which tends to be less true for freeways), travel diversions may limit arterial strategy effectiveness.

Strategies which provide reserved median lanes for express buses over substantial uninterrupted distances on major arterials appear to have potential for reducing transit travel times and diverting trips to transit, which, in turn, would have an impact on air quality. This is particularly true if preferential signal treatment and park-and-ride facilities are also provided. Such strategies are relatively costly to implement and may involve traffic safety problems, at least in the short run (as illustrated by the demonstration project experience with a median bus lane on 7th Avenue in Miami).

Although the available data do not permit a conclusive assessment, strategies employing contraflow bus lanes on major arterials (especially one-way couplets) may induce increases in transit ridership at relatively low cost. Care should be taken, however, that vehicle volumes, transit potential, and peak traffic directionality conditions are favorable for the reservation of a contraflow lane. Safety is and should be a major consideration in implementing such a facility. The available information suggests that with-flow curb bus lane strategies have minimal impacts in practice and that reserved lanes for carpools on arterials are impractical.

Although not included in this study, there are a number of arterial- and CBD-oriented strategies which substantially augment the tools considered in this study for improving downtown air quality. Auto free zones, pedestrian and transit malls, and various parking fee and parking restraint programs are among the types of strategies which might be combined with the strategies considered in this study to improve downtown air quality.

Areawide Carpool and Vanpool Programs

Documentation of Past Experience

Moderately good documentation is available on areawide carpool and vanpool strategies from both demonstration and model estimate sources (see Exhibit 5). However, in interpreting the reported results, several points should be considered:

- results are frequently available only for program participants, making it difficult to obtain a percentage impact value reflective of total regional travel;

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- ride-sharing programs and the reported results almost always focus on work trip travel, which is only a portion of total travel;

- reported "after" results for ride-sharing programs frequently focus on the near term responses among the best organized programs--participation rates may decline over time as program enthusiasm wears off and ride-sharing relationships run into difficulties; and

- the results of actual ride-sharing demonstrations and model estimates are difficult to compare or combine because the impact results tend to be reported in different forms for each and the model estimates are usually based on impact assumptions and time/cost simulation equivalences which may not be entirely compatible with the demonstration experiences.

Assessment of Strategy Impacts and Potential

Well-organized areawide carpool matching programs focusing on major employers can have a positive impact on regional air quality and reduce work trip VMT by 1 to 5 percent. Generally, employer-focused programs are more effective than decentralized, areawide programs. The major reason for this is that the reluctance to provide personal information connected with the matching program and to ride with strangers tends to be reduced when employers are actively involved in the program. With some rare exceptions, it is unlikely that areawide ride-sharing programs will have significant localized air quality impacts.

Vanpooling programs have also experienced success in certain cases for large employers. Vanpooling programs should be incorporated into an overall, integrated regional ride-sharing program. Since vanpooling is practical for large employers whose employees tend to commute more than 15 miles (one-way) to work, and since vanpooling and carpooling may be competitive, it would not be advisable to evaluate the regional air quality impacts of vanpooling as an isolated strategy.

Ride-sharing programs tend to be most effective when they are not competitive with mass transit. Thus, programs should focus on employers which are not located in downtown areas or areas not well-served by transit.

The air quality impacts of both carpool matching and vanpool programs can be significantly improved by incorporating ride-sharing incentive and single occupancy auto disincentive strategies into the overall program. Such strategies would include preferential parking for pool vehicles, lower

EXHIBIT 5

AREA-WIDE CARPOOL AND VANPOOL

STRATEGY	STRATEGY OPTION/ APPLICATION LIMITATIONS	DEMONSTRATION OR MODEL ESTIMATE DATA SOURCES*	RANGE OF REPORTED PROJECT CHARACTERISTICS				
			NUMBER OF EMPLOYERS	EMPLOYER SIZE (REQUIREMENTS)	EMPLOYEES EXPOSED		AVE. 1-WAY WORK TRIP MILEAGE
					NUMBER	% OF TOTAL	
A Area-wide Carpool Programs – Primarily Commuter Carpool Matching Service and Promotion. Actual Demonstration Results.	1. Urban Areas with 1970 SMSA Population Over 1,000,000	. New Jersey Portions of the N.Y.C. and Philadelphia AQCRs (F) . Los Angeles (Commuter Computer) (G) . San Diego (G) . New Orleans (G) . Portland, Oregon (G) . Dallas and Ft. Worth (G) . Houston (F) . Seattle (G) . Washington, D.C. (G) . Atlanta (P) . Boston (Masspool) (P)	67-850	Generally, No Specific Requirements Mentioned. For New Jersey, Employers with More Than 400 Parking Spaces. For Boston Masspool, Focus on Firms with Over 250 Daytime Employees.	100,000-621,000	16-42	6.3-22.3
	2. Urban Areas with 1970 SMSA Population of 500,000-1,000,000	. Sacramento (G) . Louisville (F) . Omaha (G) . Raleigh (F) . San Antonio (F) . Rhode Island (State-wide) (G) . Phoenix (P)	60-247	Generally, No Specific Requirements Mentioned	62,000-156,000	17-54	8.8-18.5
	3. Urban Areas with 1970 SMSA Population Below 500,000	. Tallahassee, Florida (P) . Boise, Idaho (G) . Baton Rouge, Louisiana (G) . Shreveport (P)	18-78	Generally, No Specific Requirements Mentioned	11,700-15,000	11-14	8.2-8.7
B Area-wide Carpool Programs. Model Estimates.	1. Carpool Matching and Promotion – All Employees	. Washington, D.C. (Model)					
	2. Preferential Parking for Carpools	a. . Washington, D.C. (Model)					
		b. . Birmingham, Alabama (Model)					
	3. Preferential Parking and Parking Subsidies for Carpools	a. . Washington, D.C. (Model)					
		b. . Birmingham, Alabama (Model)					
C Vanpool Programs at Individual Major Employers		. TVA, Knoxville (VG) . Aerospace Corp./Samso, Calif. (G) . Hoffman Laroch, Nutley, N.J. (VG) . 3M, St. Paul (VG) . Montgomery Ward, N. Chicago (G) . Continental Oil Co., Houston (VG)	N.A.	1,400-10,000			18-38
D Area-wide Vanpool Programs		. Sketch Planning Estimates for Baltimore		200 Employees or Greater		15-25% of Large Employers	
		1. . Modal Split Model Simulation Estimates for Washington, D.C.		500 Employees or Greater			
E Combination Area-wide Program of Carpool Matching and Promotion, Preferential Carpool Parking, and Vanpooling	Employer Focus	2. . Washington, D.C. (Model)		Carpooling Elements: 100+ Vanpooling Elements: 500+			
F Combination Program: Above Measures Plus Preferential Reserved Lane Treatment of High Occupancy Vehicles on All Appropriate Facilities.	Employer Focus	. Washington, D.C. (Model)		As Above			

* Level of Documentation E - Excellent VG - Very Good G - Good F - Fair P - Poor

@ These values are based on data collected only from employees actually participating in the carpool program.

#( ) Best Judgmental Estimates Appear in Parentheses

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EXHIBIT 5

IDE CARPOOL AND VANPOOL PROGRAMS

RTED PROJECT CHARACTERISTICS				BASE CONDITIONS AND TRAVEL IMPACTS						
MPLOYEES EXPOSED		AVE. 1-WAY WORK TRIP MILEAGE	COSTS	MATCH REQUESTS AS A % OF BASE	PERMANENT POOLS FORMED TO WORKERS EXPOSED RATIO	WORK TRIP MODAL SPLIT		PARTICIPANT AUTO OCC. 6		%Δ IN WORK VMT
ER	% OF TOTAL					BASE	ABS. % Δ	BASE	ABS. %Δ	
,000	16-42	6.3-22.3	$90,000-$600,000 Annually $13-$67 per Permanent Pool Formed (Excluding New Orleans) $.33-$2.40 Per Exposed Employee	2.3-26% of Exposed Employees (15%) # 1%-9.3% of Total Employment	0.013-0.074 (0.025)	[Available for New Jersey Only] Mode Solo Auto 67% Carpool 20% Transit 10%	 -1 +3 0	1.14-1.42 (1.25) (Excluding N.J. Statewide)	+1.1 to +1.8 (+1.5) (Excl. N.J.)	N.A.
[illegible]	17-54	8.8-18.5	$20,000-$160,000 Annually $24-$88 per Permanent Pool Formed $.55-$.89 per Exposed Employee (Limited Data)	14-21% of Exposed Employees (Limited Data) 2.6-5.9% of Total Employment	0.017-0.024 (Limited Data)	N.A.		1.0-1.8	+1.1 to +2.0 (For "After" Occupancy of 2.9-3.3)	N.A.
[illegible]	11-14	8.2-8.7	$30,000-$47,000 Annually Available for Boise Only: $29 per Permanent Pool Formed $2.33-$2.56 per Exposed Employee	16-29% of Exposed Employees 3.3-12% of Total Employment	For Boise Only: 0.008	N.A.		1.2	+1.33 to +1.5	N.A.
						Drive Alone: 52.9 Shared Ride: 25.4 Transit: 14.5	-2.1 +4.2 -0.7			-1 to -1.8 (For Work and Nonwork Trips Combined: -0.4)
						Drive Alone: 52.9 Shared Ride: 25.4 Transit: 14.5	-5.7 +5.6 +0.1	1.35 (These are for All Work Trips, Not Just for Participants)	+.02	-1 to -3.4 (For Work and Nonwork Trips Combined: -0.8)
						Drive Alone: 67.7 Shared Ride: 23.9 Transit: 8.0	-4.3 +4.3 +0.0			-1.9 (For Work and Nonwork Trips Combined: -0.1)
						Drive Alone: 52.9 Shared Ride: 25.4 Transit: 14.5	-11.8 +11.1 +0.7			-9.8 (For Work and Nonwork Trips Combined: -2.2)
						Drive Alone: 67.7 Shared Ride: 23.9 Transit: 8.0	-13.0 +12.3 +1.0			-10.3 (For Work and Nonwork Trips Combined: -1.6)
		18-38	Employer: .5-2 Full Time Employees (Also $6,500 Per Year) Vans and Operating: Usually Covered by Fares		14-75 Vans Carrying 150-830 Passengers	Drive Alone: 65-90% Carpool: 7-30% Vanpool: 0 Transit: 3- 4% Other: 0-1.5% ** Source of Vanpool Shift: Drive Alone: 42-49% Carpool: 50-58% Transit: 1% and Above	+.4 to +16**	1.15-1.63	N.A.	
	15-25% of Large Employers			2,300 Vans with Average Occupancy of 10						-8.3 Net Peak -3 Net Daily
						Assumed 9.4% Area-wide Vanpool Share Drive Alone: 52.9 Shared Ride: 25.4 Transit: 14.5 Vanpool: 0	 -3.7 -3.2 -2.6 +9.4			-5.3 (For Work and Nonwork Trips Combined: -1.2)
						Drive Alone: 52.9 Shared Ride: 25.4 Transit: 14.5 Vanpool: 0	-5.5 +3.4 -0.3 ?			-6.6 (For Work and Nonwork Trips Combined: -1.7)
						Drive Alone: 52.9 Shared Ride: 25.4 Transit: 14.5 Vanpool: 0	-5.8 +3.7 -0.3 ?			-7.1 (For Work and Nonwork Trips Combined: -1.8)

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rate or free parking for pool vehicles, and special employer incentives for employee pool members. While many of these strategies are themselves beyond the scope of this study, they are noted to emphasize the importance of an integrated metropolitan area transportation control plan incorporating both regional and local elements.

Overall, well planned and implemented carpool matching and vanpool programs are likely to be cost-effective. The challenge faced by these organized ride-sharing programs is to surmount the barriers resulting from variable working hours, on-the-job auto requirements, home or work location, and strong travel preference for driving alone.

Transit Fare Reductions and Service Improvements

Transit improvement strategies are an essential element of any comprehensive program to improve air quality by providing low-occupancy vehicle disincentives and high-occupancy vehicle incentives. These programs can only be effective if an attractive alternative is provided which does not involve a severe loss of mobility or travel amenities. Some of the many transit improvement strategies which may be included in such an incentive/disincentive package are: reducing transit fares; improving transit facilities (shelters, etc.); improving security arrangements; expanding bus services, especially express bus services; marketing programs; fare collection methods (use of discount passes, tokens); and providing paratransit services.

In addition to serving as a necessary element of comprehensive transportation programs, public transit improvements promote air pollution and VMT reductions. Fare reductions and service initiation or expansion focused on radial express bus service could have a significant impact on localized CO problems in major commuting corridors, especially when combined with strategies giving priority freeway or arterial treatment.

Expanded radial express bus service can be a cost-effective approach for achieving air quality improvements. Substantial regional fare reductions and service improvements can generate substantial transit ridership increases--up to 25 percent or more, but these programs can be costly. The relatively low cost-effectiveness ranking of these approaches is the result of the price inelasticity of transit ridership (typically an elasticity in the neighborhood of -0.3) and the difficulty of translating any marginal increase in transit service into a perceived improvement in service for a significant number of potential users.

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When estimating the effectiveness of such strategies for improving air quality, the following factors should be considered:

- the greatest percentage gains tend to be in areas where the base transit share is relatively small;
- VMT and associated emission reductions may be offset to some extent by the alternate use of automobiles left home by commuters;
- in most areas, transit can effectively serve only a limited number of origins and destinations;
- ridership gains usually contain a large percentage of trips which were induced, previously made by walking, or previously made as an auto passenger;
- ridership gains are often greatest in off-peak rather than peak periods, reducing the localized air quality improvement potential of such gains; and
- air pollution reductions resulting from transit ridership gains are partially offset by additional bus emissions associated with the service increases.

Transit strategies focused on intra-CBD travel for large urban regions might attract significant ridership. However, the air quality improvements achieved by such strategies are likely to be limited because:

- the majority of ridership increases are associated with induced travel and tripmakers who formerly walked or were auto passengers;
- a very large portion of such ridership increases are during off-peak travel periods; and
- improved service levels must be carefully balanced against bus utilization for reasons of cost and net air quality impact.

Other CBD strategies not considered in this report (e.g., auto free zones, area licensing, transit malls, and parking management) may be capable of achieving a greater reduction in CBD CO concentrations.

EXHIBIT 6

TRANSIT FARE REDUCTIO
SERVICE IMPROVEMEN

STRATEGY	STRATEGY OPTION/ APPLICATION LIMITATIONS	DEMONSTRATION OR MODEL ESTIMATE DATA SOURCES*	RANGE OF REPORTED PROJECT CHARACTERISTICS			
			FARE CHANGES	SERVICE CHANGES	COSTS	BASE
A. Uniform Percentage Fare Reductions		1. . St. Louis (F)	Decrease From $.45 to $.25 (–44%)			
		2. . Washington, D.C (Model)	–10%			431,400
			–25%			431,400
B. Non-Uniform Fare Reductions		1. . Cincinnati (Model)	Before $.55-$1 After: $.25-$.60; $.10 Transfer Now Free. Overall Change Approx. -40% to –55%		$1 Million Loss in Revenues	5,625,000 Annually
		2. . Denver (F)	Before After $.40 $.35 Adult $.40 $.25 Senior $.30 $.25 Child/ Student $.05 $.05 Transfer			
C. Elimination of Transit Fares	1. Area-wide Fare Change	a. Boston (Model)	Elimination of $.25 Fare	Unspecified		
		b. . Auburn, N.Y. (F)	Elimination of $.25 Fare (1 Month)			18,000 Monthly
	2. Downtown Area Fare Change	a. . Seattle (P)	Elimination of $.20 Fare Downtown			
		b. . Dayton (F)	Elimination of Fare in 66-Block Area of CBD			
D. Increase in Bus Miles of Service	1. New Bus Service	. Orange County (F)	No Change: $.25-$.50 Base Fare	Initiation of 21,000 Bus Miles of Intra-County Daily Bus Service with Inter-County Connections		24,000 Daily Trips (1.14 Trips per Bus-Mile of Service)
	2. Expansion of Existing Bus Service	. Washington, D.C. (G)		16.4% Increase in Bus Miles		453,000 Daily
E. Increased Bus Frequency to CBD		Washington, D.C. (Model)		Increase in Service Frequency to CBD of 20%		
				Increase in Service Frequency to CBD of 40%		
F. Initiation of New Express Bus Service	On Freeway in Mixed Traffic	. Seattle (Blue Streak Service) (F)		New 9-Mile Express Bus Service (81 Daily Bus Trips) on Freeway, in Mixed Traffic. Fringe Parking Provided.		Estimate of Pre-Demonstration Express Bus Ridership: 7,500 daily
G. Combined Increase in Bus Frequency and Provision of Express Bus Service for CBD		. Washington, D.C. (Model)		Institution of Express Bus Service to CBD and Increase in Bus Frequency to CBD of 20%		
H. Combined Fare Reductions and Service Improvements		1. . Atlanta (Model)	Decrease in Fares From $.40 to $.15 (–63%) Elimination of $.05 Transfer Charge	. 17.2 % Increase in Bus-Miles Supplied (From 64,000 to 75,000 Daily) . Extend 16 Lines . Add 14 Lines . Modify 18 Lines		185,000 Daily
		2. . San Diego (G)	Base Fare Reduced From $.40 to $.25 and All Zone Charges Eliminated (Approx. 39% Overall Reduction). Also, Monthly Pass Reduced From $16-36 to $10.	Change in Daily Bus-Miles Provided: Year Miles %Δ 1972 27,000 – 1973 35,000 +29 1974 58,000 +66		Daily: 1972: 51,000 1973: 82,000 1974: 104,000
		3. . Los Angeles (G)	Introduced Flat Fares Instead of Zone Fares: Adult $.25 Student $.15 Senior $.10 Transfer $.10 Average Fare Decreased From $.34 to $.23 (–32%)	Added Buses to Existing Routes and a Limited Number of New Routes Added. Weekly Bus Miles Increased From 2,316,570 to 2,462,130 (+6.3%)		587,209 Daily (For SCRTD Service)

* Level of Documentation: E - Excellent VG - Very Good G - Good F - Fair P - Poor

#( ) - Best Judgmental Estimates Appear in Parentheses

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EXHIBIT 6

TRANSIT FARE REDUCTIONS AND SERVICE IMPROVEMENTS

OJECT CHARACTERISTICS		BASE CONDITIONS AND TRAVEL IMPACTS							
		TRANSIT RIDERSHIP					MODAL SPLIT		%Δ IN AUTO VEHICLE TRAVEL
SERVICE CHANGES	COSTS	BASE	%Δ	SOURCE OF Δ	PRICE ELASTICITY	SERVICE ELASTICITY	BASE	ABS. %Δ	
			+15 (+8 to +10 Peak; +24 to +26 Off Peak)		-0.34				
		431,400	+1.64		-.16		Transit 20% Auto Driver 59% (Auto Occ 1.35)	+0.33 -.19 -.07%)	.3 Auto Driver Work Trips
		431,400	+4.12		-.16		Transit 20% Auto Driver 59% (Auto Occ 1.35)	+0.82 -0.50 -.18%)	-.8 Auto Driver Work Trips
	$1 Million Loss In Revenues	5,625,000 Annually	+32		-.38				
			+10 Peak +25 Off-Peak		-.61 Peak -.99 Off Peak				
Unspecified			+20 Peak Hour +30 Off Peak +28 to +32 Total		-.17 Work -.28 Shopping				-6 to -9 VMT Change for Boston Proper
		18,000 Monthly	+389		-.7				
			+56 Downtown						
			Several Hundred % Increase In 66-Block Area.+14% System-Wide	Auto 28% Pedestrian 48% Remainder an Increase in Transit Usage by Past Users					
Initiation of 21,000 Bus Miles of Intra-County Daily Bus Service with Inter-County Connections		24,000 Daily Trips (1.14 Trips per Bus-Mile of Service)							
16.4% Increase in Bus Miles		453,000 Daily	+.66						
in Service Frequency to CBD							Ride Alone: 52.9 Shared Ride: 25.4 Transit: 14.5	-0.5 -0.6 +1.0	-0.1 Total VMT
in Service Frequency to CBD							Ride Alone: 52.9 Shared Ride: 25.4 Transit: 14.5	-1.0 -1.2 +2.2	-0.2 Total VMT
8-Mile Express Bus Service (81 y Bus Trips) on Freeway, in Mixed c. Fringe Parking Provided.		Estimate of Pre-Demonstration Express Bus Ridership: 7,500 daily	+49	Mode Prior to Blue Stream. Auto Driver 16% Auto Passenger 5% Transit 61% Did Not Make Trip 18%					
tion of Express Bus Service to CBD ncrease in Bus Frequency to CBD of							Ride Alone: 52.9 Shared Ride: 25.4 Transit: 14.5	-0.9 -1.0 +2.0	-0.29 Total VMT
2% Increase in Bus-Miles Supplied om 64,000 to 75,000 Daily) nd 16 Lines 14 Lines fy 18 Lines		185,000 Daily	Weekday: +28 Saturday: +41 Sunday: +79	91% of Δ From New Riders. Previous Mode Auto Driver 42% Auto Pass. 22% Other Vehicles 10% Walk 4% Trip Not Made 22%	-.15 to -.20	+.3 with Respect to Bus-Miles			
in Daily Bus-Miles Provided: Miles %Δ 27,000 – 35,000 +29 58,000 +66		Daily: 1972: 51,000 1973: 82,000 1974: 104,000	– +61 +27						
Buses to Existing Routes and ed Number of New Routes Added. Bus Miles Increased From 2,316,570 2,130 (+6.3%)		587,209 Daily (For SCRTD Service)	+17.2	Auto Driver 58% Auto Pass. 21% Did Not Make Trip 10% No Response 10%					

8

TRANSPORTATION PROGRAMS RECOMMENDED FOR DETAILED SCENARIO ANALYSIS

The strategies considered in this report have the potential for achieving improvements in regional air quality--especially when combinations of strategies which include strong incentives and disincentives (e.g., auto restricted zones, pricing) not within the scope of this report are included in the total transportation control plan. On the basis of the literature review and analysis of demonstration projects, the strategies which appear to have the greatest potential for achieving improvements in localized CO air quality in a cost-effective manner include:

- With-flow freeway lanes reserved for buses and carpools;
- Contraflow bus lanes on freeways;
- Metered freeway access ramps with bus by-pass lanes;
- Contraflow bus lanes on major one-way arterial pairs;
- Provision of high level express bus service with reduced fares, operating in mixed traffic on major arterials or freeways;
- Provision of high level express bus service (possibly with reduced fares), combined with a reserved lane for buses and carpools on the appropriate freeway facility; and
- Provision of high level express bus service (possibly with reduced fares), combined with a reserved median lane for buses and bus preemption of traffic signals on an appropriate arterial.

For regional air quality impacts, it is suggested that emphasis be placed on the analysis of integrated areawide ride-sharing programs directed at large employers and including carpool matching, vanpool formation assistance, and promotional components. It would also be advisable to analyze the regional impacts of an areawide program to apply one or more of the above listed "localized" strategies to all appropriate facilities in the region.

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It is emphasized that the contribution which transportation strategies such as the above can make to improving both regional and localized air quality can be significantly enhanced by developing a total, integrated regional and localized program for achieving air quality. Such a program would incorporate strategies such as those listed above as well as strategies which are beyond the scope of this report.

III. TRAVEL, AIR QUALITY, AND RELATED IMPACTS OF SELECTED TRANSPORTATION PROGRAMS

This section presents and assesses the results of the 20 prototype scenario analyses. These prototype scenarios were designed to provide representative findings on the range of travel, air quality/emission, fuel consumption, cost, and economic impacts of TSM programs which appear to have potential for localized or regional air quality improvement.

PROTOTYPE SCENARIOS SELECTED FOR DETAILED ANALYSIS

Selection and Significance of the Scenarios

Based on the findings presented in Section II, a total of 20 prototype scenarios were selected for analysis and evaluation. These scenarios were defined to encompass the most promising carpool/vanpool, reserved lane, and transit improvement strategies and combination programs.

Ten of the scenarios deal with strategies which impact specific highway corridors, thus affecting only a limited portion of total regional travel. The analysis of these "localized" scenarios therefore focuses on their carbon monoxide (CO) concentration impacts near the affected highway facilities. The remaining ten scenarios have areawide travel impacts. The analysis of these latter, "regional" scenarios thus focuses on their regional pollutant emission impacts.

The scenarios were designed with some systematic variation in assumed travel impacts and area size to facilitate generalizing the project's findings. However, the extent of this planned variation in assumed prototype conditions was limited by the number of scenarios analyzed in total and the need for a minimum degree of uniformity among scenarios (so that impact estimates among different strategies would be comparable).

With this general background, the following specific points should be made about the prototype scenarios:

- Although designed to be illustrative of typical implementation conditions and the impacts of some variability in these conditions, the scenarios should not be interpreted as yielding the answer for a given strategy; nor do they span the range of typical variation in all major factors. As will be demonstrated later in this section, the air quality impacts of a specific strategy implementation can vary substantially, depending on the specifics (travel conditions, meteorology, highway geometrics, etc.) of the application.

- As a very rough surrogate for the variability in some of these factors, the concept of "moderately favorable impacts" versus "modest impacts" has been introduced into the description of scenarios. Most of the scenarios assume "moderately favorable impacts." In other words, base modal split, congestion levels and the advantages actually achieved by high occupancy vehicles under the proposed actions are assumed to be those which result in a reasonably favorable air quality impact (although within the range of actual past experience). For comparison purposes, several scenarios have been defined the same as another, except for an assumption of "modest impacts." The travel shifts assumed for these scenarios are toward the lower end of past experience, but not intended to be extremely unfavorable.

Localized Prototype Scenarios

Exhibit 7 describes the 10 prototype scenarios selected for analysis of localized CO concentration impacts. These scenarios will be identified throughout this report by the ID number and brief title assigned each in the exhibit. The major descriptive features and travel impact assumptions for each scenario are presented in the table. Further details on the travel impact analysis methodology appear in Appendix A. The third column of Exhibit 7 references illustrative diagrams in Exhibit 8 which display the highway facilities assumed for each scenario.

The first eight localized scenarios deal with the priority treatment of high occupancy vehicles on freeways, while the last two deal with priority treatment of buses on arterials. The programs being implemented in a scenario typically consist of several complementary actions, such as reserving a freeway lane, expanding express bus service, and providing park-and-ride lots in the corridor. As indicated in Section II, such combinations are typical of actual transportation programs implemented throughout the nation.

Regional Prototype Scenarios

Exhibit 9 presents and describes the 10 scenarios selected for analysis of regional HC, NO_x, and CO emission impacts. Comments analogous to those made above about Exhibit 8 and the localized scenarios apply here.

EXHIBIT 7

LOCALIZED SCENARIOS SELECTED FOR DETAILED ANALYSIS

PROTOTYPE SCENARIO		ILLUSTRATIVE DIAGRAM*	DESCRIPTION OF THE STRATEGY OR PROGRAM IMPLEMENTED	MAJOR ASSUMPTIONS ON CHANGES IN MODAL USAGE**
ID NO.	TITLE			
1	Expanded Express Bus Service in Mixed Freeway Traffic; Favorable Impacts	A	• 10 Mile, 8 Lane Freeway, No Reserved Lanes • Expanded, Reduced Fare Express Bus Service, Operating in Mixed Freeway Traffic During Peak Periods • Three 500 Space Park-and-Ride Lots in Corridor	(Moderately Favorable Impacts) • 50% Increase in Freeway Express Bus Ridership • No Increase in Freeway Carpools
2	Freeway Lane Reserved for Buses and Carpools; Favorable Impacts	A	• 10 Mile, 8 Lane Freeway, With-Flow Lane Reserved for Buses and Carpools (3+ Occupants) • Expanded Express Bus Service During Peak Periods • Three 500 Space Park-and-Ride Lots in Corridor	(Moderately Favorable Impacts) • 100% Increase in Freeway Express Bus Ridership • 100% Increase in Freeway Carpools
3	Ramp Metering and Bus By-Pass Lanes; Favorable Impacts	B	• 15 Mile, 8 Lane Freeway; Metering of All On-Ramps • Bus By-Pass Lanes at 4 Ramps • Expanded Express Bus Service During Peak Periods • Three 500 Space Park-and-Ride Lots in Corridor	(Moderately Favorable Impacts) • 100% Increase in Freeway Express Bus Ridership • No Increase in Freeway Carpools
4	Reserved Bus/Pool Lane, Ramp Metering, and Bus By-Pass Lanes; Modest Impacts	B	• 15 Mile, 8 Lane Freeway; Metering of All On-Ramps • Bus By-Pass Lanes at 4 Ramps • With-Flow Lane Reserved for Buses and Carpools (3 + Occupants) • Expanded Express Bus Service During Peak Periods • Three 500 Space Park-and-Ride Lots in Corridor	(Modest Impacts) • 75% Increase in Freeway Express Bus Ridership • 50% Increase in Freeway Carpools
5	Reserved Bus/Pool Lane, Ramp Metering, and Bus By-Pass Lanes; Favorable Impacts	B	• Same as Scenario 4	(Moderately Favorable Impacts) • 125% Increase in Freeway Express Bus Ridership • 95% Increase in Freeway Carpools
6	Contraflow Freeway Lane Reserved for Buses; Favorable Impacts	C	• 10 Mile, 6 Lane Freeway; Off-Peak Direction Contraflow Lane Reserved for Express Buses • Existing Freeway Express Bus Service Expanded Only to Meet Increased Demand	(Moderately Favorable Impacts) • 50% Increase in Freeway Express Bus Ridership • No Increase in Freeway Carpools

(Continued)

*SEE EXHIBIT 8 FOR ILLUSTRATIVE DIAGRAMS OF THE PROTOTYPE HIGHWAY FACILITIES

**SEE APPENDIX A FOR FURTHER DETAIL ON METHODOLOGY AND TECHNICAL ASSUMPTIONS

EXHIBIT 7

LOCALIZED SCENARIOS SELECTED FOR DETAILED ANALYSIS (Cont'd)

PROTOTYPE SCENARIO		ILLUSTRATIVE DIAGRAM*	DESCRIPTION OF THE STRATEGY OR PROGRAM IMPLEMENTED	MAJOR ASSUMPTIONS ON CHANGES IN MODAL USAGE**
ID NO.	TITLE			
7	Contraflow Bus Lane, Expanded Express Bus Service, and Park-and-Ride Lots; Favorable Impacts	C	• 10 Mile, 6 Lane Freeway; Off-Peak Direction Contraflow Lane Reserved for Express Buses • Expanded Freeway Express Bus Service During Peak Periods • Three 500 Space Park-and-Ride Lots in Corridor	(Moderately Favorable Impacts) • 120% Increase in Freeway Express Bus Ridership • No Increase in Freeway Carpools
8	Contraflow Bus Lane, Expanded Service, and Lots; Assuming 70%/30% Directional Split; Favorable Impacts	C	Same as Scenario 7, except: 70%/30% Directional Split of Peak Hour Freeway Traffic Assumed Instead of 60%/40% (Assumed in Other Scenarios)	Same as Scenario 7
9	Reserved Arterial Median Lane for Express Buses; Favorable Impacts	D	• 10 Mile, 5 Lane Arterial; Reversible Median Lane Reserved for Express Buses • New Express Bus Service at Reduced Fares • Signal Pre-Emption for Express Buses • Two 250 Space Park-and-Ride Lots in Corridor	(Moderately Favorable Impacts) • Express Bus Ridership Achieved Which Yields Overall (Local Plus Express) Bus Modal Split of 40% in Corridor
10	Contraflow Curb Lane for Local Buses on Pair of One-Way Arterials; Favorable Impacts	E	• 1 Mile Segment, Pair of One-Way 4 Lane Arterials; Contraflow Curb Lane Reserved for Local Buses • Express Buses Do Not Use Contraflow Curb Lane	(Moderately Favorable Impacts) • 15% Increase in Local Bus Ridership

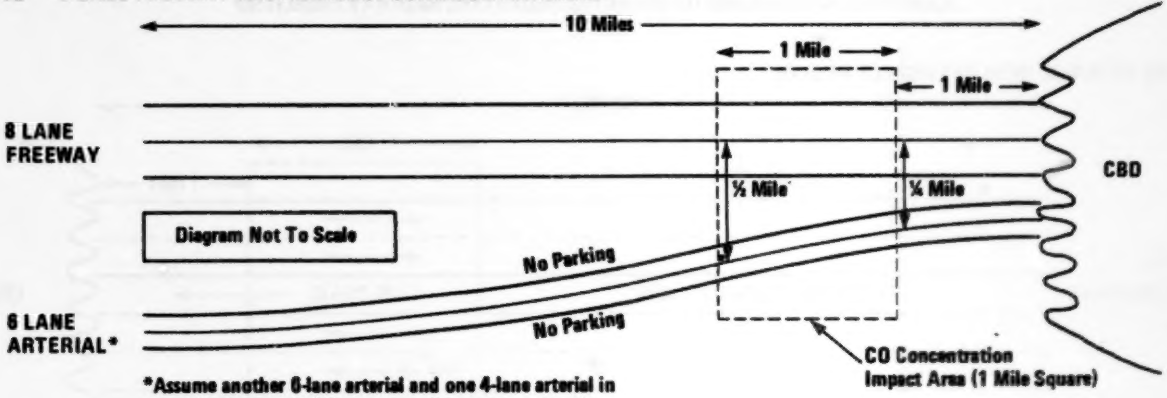
*SEE EXHIBIT 8 FOR ILLUSTRATIVE DIAGRAMS OF THE PROTOTYPE HIGHWAY FACILITIES

**SEE APPENDIX A FOR FURTHER DETAIL ON METHODOLOGY AND TECHNICAL ASSUMPTIONS

EXHIBIT 8

ILLUSTRATIVE DIAGRAMS OF AFFECTED PROTOTYPE HIGHWAY FACILITIES

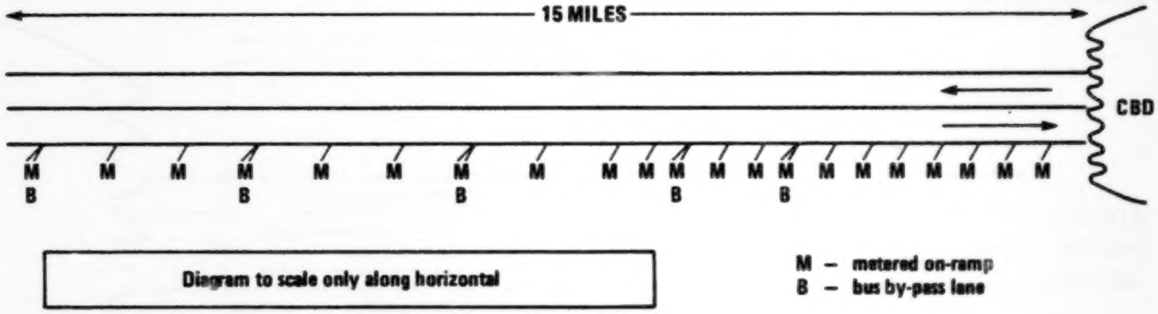
A. 8 LANE FREEWAY AND ADJACENT CORRIDOR ARTERIAL



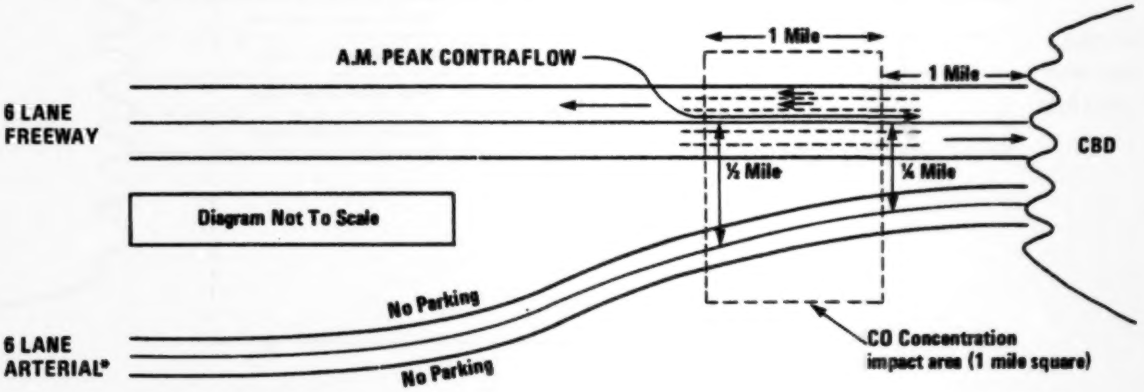
*Assume another 6-lane arterial and one 4-lane arterial in corridor for travel shift purposes, but not crossing the designated CO concentration impact area

B. 8 LANE FREEWAY WITH RAMP METERING AND ADJACENT CORRIDOR ARTERIAL

SAME AS DIAGRAM A, EXCEPT THAT THE FREEWAY IS EXPLICITLY ASSUMED TO EXTEND OUT FROM CBD 15 MILES AND THE LOCATION OF ON-RAMPS (METERED) AND BUS BY-PASS LANES ARE NOW INDICATED (ONLY CHANGED FEATURES SHOWN BELOW):


15 MILES
CBD
M M M M M M M M M M M M M M M M M M M M M M
B B B B B
Diagram to scale only along horizontal
M – metered on-ramp
B – bus by-pass lane

C. 6 LANE FREEWAY AND ADJACENT CORRIDOR ARTERIAL

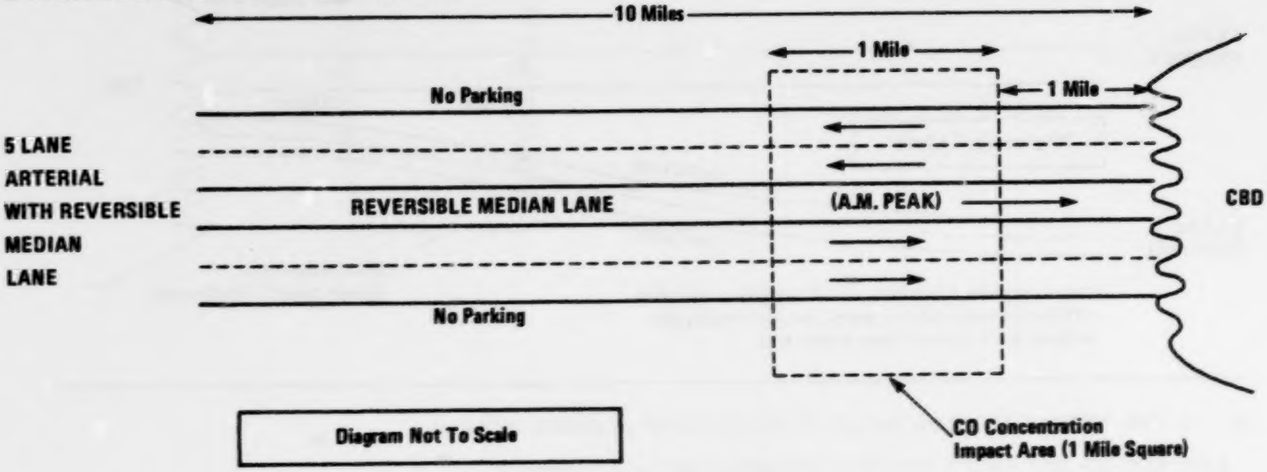


*Assume another 6-lane arterial in corridor for travel shift purposes, but not crossing the designated CO concentration impact area.

EXHIBIT 8 (Cont'd)

ILLUSTRATIVE DIAGRAMS OF AFFECTED PROTOTYPE HIGHWAY FACILITIES

D. 5 LANE ARTERIAL WITH REVERSIBLE MEDIAN



E. PAIR OF 4 LANE ONE-WAY ARTERIALS

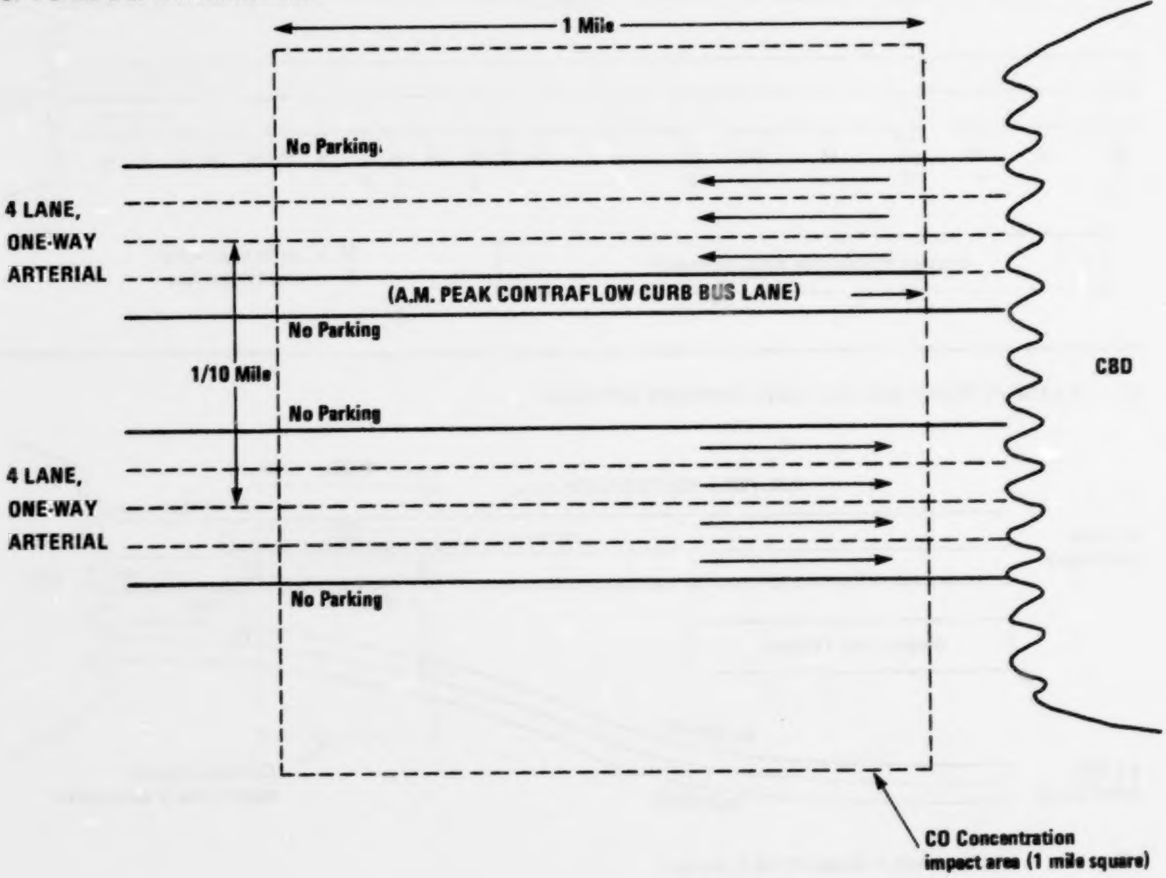


EXHIBIT 9

REGIONAL SCENARIOS SELECTED FOR DETAILED ANALYSIS

PROTOTYPE SCENARIO		DESCRIPTION OF THE STRATEGY IMPLEMENTED AND THE AFFECTED FACILITIES OR TRAVEL MARKET*	MAJOR ASSUMPTIONS ON CHANGES IN MODAL USAGE**
ID No.	TITLE		
11	Carpool/Vanpool Program, Medium Size City; Favorable Impacts	• Areawide Carpool Matching Program for Employers of 200+ (40% of Employees) • Areawide Vanpool Program for Employers of 1,000+ (20% of Employees)	(Moderately Favorable Impacts) • 8% of Employees of Participating Employers Form New Carpools • 3% of Employees of Participating Employers Form New Vanpools
12	Carpool/Vanpool Program, Large City; Favorable Impacts	• Areawide Carpool Matching Program for Employers of 200+ (30% of Employees) • Areawide Vanpool Program for Employers of 1,000+ (17% of Employees)	(Moderately Favorable Impacts) • Approx. 7% of Employees of Participating Employers Form New Carpools • 3% of Employees of Participating Employers Form New Vanpools
13	Reserved Bus/Pool Lanes, Ramp Metering, and Bus By-Pass Lanes on All Appropriate Freeways; Modest Impacts	• Expanded Reduced Fare Express Bus Service on Freeways • Reserved With-Flow Lane for Buses and Carpools (3+ Occupant) on Approximately 48 miles of 8 Lane Radial Freeway • Ramp Metering on On-Ramps and 16 Bus By-Pass Ramps • Expanded Fringe Parking Facilities	(Modest Impact) • 75% Increase in Affected Express Bus VMT • 50% Increase in Affected Carpool VMT • Associated Decreases in Auto VMT
14	Reserved Bus/Pool Lanes, Ramp Metering, and Bus By-Pass Lanes on All Appropriate Freeways; Favorable Impacts	Same as Scenario 13	(Moderately Favorable Impacts) • 125% Increase in Affected Express Bus VMT • 95% Increase in Affected Carpool VMT • Associated Decreases in Auto VMT
15	Reserved Median Lane for Express Buses on Appropriate Radial Arterials; Modest Impacts	• New Reduced Fare Express Bus Service on Reserved Reversible Median Lane of 72 Miles of Major Radial Arterials • Signal Pre-Emption for Express Buses • Expanded Fringe Parking Facilities	(Modest Impact) • VMT Increase for Express Bus Associated With a 30% Overall (Local and Express) Bus Modal Split for Affected Corridor Travel • Associated Decrease in Auto VMT
16	Reserved Median Lane for Express Buses on Appropriate Radial Arterials; Favorable Impacts	Same as Scenario 15	(Moderately Favorable Impacts) • VMT Increase for Express Bus Associated With a 40% Overall (Local and Express) Bus Modal Split for Affected Corridor Travel • Associated Decrease in Auto VMT

(Continued)

*ALL SCENARIOS EXCEPT FOR #11 ARE FOR A "LARGE" CITY (1,000,000+ SMSA POPULATION RANGE). SCENARIO #11 IS SET IN A MEDIUM SIZED CITY (500,000 - 1,000,000 SMSA POPULATION RANGE).

**SEE APPENDIX A FOR FURTHER DETAIL ON METHODOLOGY AND TECHNICAL ASSUMPTIONS.

EXHIBIT 9

REGIONAL SCENARIOS SELECTED FOR DETAILED ANALYSIS (Cont'd)

PROTOTYPE SCENARIO		DESCRIPTION OF THE STRATEGY IMPLEMENTED AND THE AFFECTED FACILITIES OR TRAVEL MARKET*	MAJOR ASSUMPTIONS ON CHANGES IN MODAL USAGE**
ID No.	TITLE		
17	Carpool/Vanpool Program and Freeway Reserved Lanes; Modest Impacts	• Carpool/Vanpool Program as Described in Scenario 12 • Expanded Reduced Fare Express Bus Service on Freeways • Reserved With-Flow Lane for Buses and Carpools (3+ Occupant) on Approximately 40 Miles of 8 Lane Radial Freeway • Expanded Fringe Parking Facilities	(Modest Impacts) Carpool/Vanpool Component • 50% of VMT Impacts in Scenario 12 Reserved Lane Program Components • 55% Increase in Affected Express Bus VMT • 65% Increase in Affected Carpool VMT • Decrease in Auto VMT Associated With Above Two Shifts
18	Carpool/Vanpool Program and Freeway Reserved Lanes; Favorable Impacts	Same as Scenario 17	(Moderately Favorable Impacts) Carpool/Vanpool Component • Same Carpool/Vanpool Impacts as Scenario 12 Reserved Lane Program Components • 100% Increase in Affected Express Bus VMT • 100% Increase in Affected Carpool VMT • Decrease in Auto VMT Associated With Above Two Shifts
19	Carpool/Vanpool Program, Reserved Lanes, Ramp Metering, and Bus By-Pass Lanes; Modest Impacts	• Carpool/Vanpool Program as Described in Scenario 12 • Reserved Lane Freeway Program as Described in Scenario 13	(Modest Impacts) Carpool/Vanpool Component • 50% of VMT Impacts of Scenario 12 Freeway Program Components • Same as Scenario 13
20	Carpool/Vanpool Program, Reserved Lanes, Ramp Metering, and Bus By-Pass Lanes, Favorable Impacts	Same as Scenario 19	(Moderately Favorable Impacts) Carpool/Vanpool Component • Same as Scenario 12 Freeway Program Components • Same as Scenario 14

*ALL SCENARIOS EXCEPT FOR #11 ARE FOR A "LARGE" CITY (1,000,000+ SMSA POPULATION RANGE). SCENARIO #11 IS SET IN A MEDIUM SIZED CITY (500,000 - 1,000,000 SMSA POPULATION RANGE).

**SEE APPENDIX A FOR FURTHER DETAIL ON METHODOLOGY AND TECHNICAL ASSUMPTIONS.

The first two regional scenarios (11 and 12) deal with areawide carpool/vanpool programs focused on major employers in a prototype medium-sized region (500,000-1 million population) and large region (1 million + population) respectively. Scenarios 13 and 14 deal with the application of a combination freeway corridor strategy for several corridors throughout the region. Scenarios 15 and 16 do the same for a combination arterial strategy. The last four strategies involve the combination of both areawide carpool/vanpool and freeway corridor strategy components.

LOCALIZED SCENARIO IMPACT ESTIMATES

In this section, the following impacts are presented and discussed for each of the 10 localized scenarios:

- travel impacts and highway noise impacts;
- localized CO concentration impacts;
- capital and operating costs; and
- economic impacts.

Travel and Highway Noise Impacts

The estimation of travel impacts for each scenario was a critical first step in the analysis. Estimates of emissions, localized CO concentration, and highway noise impacts all follow from the travel impact estimates.[1] For the localized scenarios which focus on specific freeway or arterial facilities, these impacts include changes in vehicle volume and speed for each major vehicle type (auto, carpool, bus, and truck).

Aside from their use as input to air quality and other impact estimates, travel impact estimates are valuable for strategy or program assessment and evaluation in their own right. Travel time and congestion impacts are both significant evaluation considerations. Examining the detailed travel impacts of a strategy under given prototype conditions can also supply valuable information on operational requirements (e.g., signing, enforcement) and potential trouble areas; (e.g., congestion points, traffic "conflict" locations); ways in which a strategy might be implemented under specific conditions to provide more desirable impacts may also be suggested.

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[1] See Table A. 1 of Appendix A for a flowchart of the overall analysis and impact estimation procedure.

Exhibit 10 summarizes the major travel impacts estimated for the 10 localized scenarios. Vehicle volumes and average speeds for A.M. peak hour, peak direction travel are given by vehicle type for both the base conditions ("before") and after the scenario strategy has been implemented ("after"). These values pertain to a segment of the primary highway facility in the prototype corridor which has been selected as the focus of the illustrative CO concentration impact area. This impact area is a one mile square which has its inner edge approximately one mile from the CBD of the prototype region for most of the scenarios.[1]

Exhibit 10 also presents information on the congestion impacts of each scenario strategy in the form of "before" and "after" volume-to-capacity (V/C) ratios for each prototype facility element in both the peak and off-peak directions. Several major points should be made concerning the interpretation of these impacts:

- The travel impacts reported are intended to be representative of typical conditions and reasonable expectations for modal shifts, but are nevertheless illustrative. The actual travel impacts achieved in applying the scenario strategy or program to a specific corridor would depend on base travel conditions, highway facility geometrics, details of implementation, and similar factors prevailing for the specific application.

- In some cases, the removal of a lane from normal service and reservation for use by high occupancy vehicles (HOV) results in over-capacity congestion (V/C ratio greater than 1.00) in the remaining non-reserved lanes. Since stable flow conditions are frequently lost and average speeds may not be reliably estimated under such over-capacity conditions, speeds below the at-capacity (level of service E) level are not reported in the table. However, these cases are noted and rough estimates of additional stop-and-go delay are provided.

- In two of the scenarios (6 and 7), reservation of an off-peak direction freeway lane for contraflow bus operation results in off-peak direction traffic (which originally experienced good peak hour flow conditions) facing capacity congestion levels.

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[1] The illustrative diagrams in Exhibit 8 indicate the CO impact area with a dotted line.

EXHIBIT 10

MAJOR TRAVEL IMPACTS FOR LOCALIZED SCENARIOS

PROTOTYPE SCENARIO		A.M. PEAK HOUR TRAVEL CONDITIONS IN CO IMPACT AREA							
ID No.	TITLE	PEAK DIRECTION VEHICLE VOLUMES AND AVERAGE SPEEDS ON PRIMARY CORRIDOR FACILITY					VOLUME TO CAPACITY RATIO CONGESTION LEVELS*		
1	Expanded Express Bus Service in Mixed Freeway Traffic; Favorable Impacts	On Corridor Freeway:						V/C	RATIO*
								BEFORE	AFTER
			BEFORE		AFTER		Freeway		
		Vehicle Type	VPH	MPH	VPH	MPH	Peak Direction	1.00	0.87
		Auto	6,290	28	6,050	28	Off-Peak Direction	0.67	0.67
		Carpool	330	28	320	28			
		Bus	28	28	52	28	Corridor Arterial		
		Truck	350	28	350	28	Peak Direction	0.75	0.74
			7,000		6,770		Off-Peak Direction	0.50	0.50
					(-3.1%)				
2	Freeway Lane Reserved for Buses and Carpools; Favorable Impact	On Corridor Freeway						V/C	RATIO*
								BEFORE	AFTER
			BEFORE		AFTER		Freeway		
		Vehicle Type	VPH	MPH	VPH	MPH	Reserved Lane	1.00	0.41
		Auto	6,290	28	5,030	28**	Non-Reserved, Peak Dir.		1.02
		Carpool	330	28	600	43	Off-Peak Direction	0.67	0.67
		Bus	28	28	58	43			
		Truck	350	28	350	28**	Corridor Arterial		
			7,000		6,040		Peak Direction	0.75	0.70
					(-13.7%)		Off-Peak Direction	0.50	0.50
		**Does not include effects of additional stop-and-go delay (estimated at over 0.5 minute) caused by over-capacity congestion.							
3	Ramp Metering and Bus By-Pass Lanes; Favorable Impacts	On Corridor Freeway:						V/C	RATIO*
								BEFORE	AFTER
			BEFORE		AFTER		Freeway		
		Vehicle Type	VPH	MPH	VPH	MPH	Peak Direction	1.00	0.83
		Auto	6,290	28	5,810	30	Off-Peak Direction	0.67	0.67
		Carpool	330	28	310	30			
		Bus	28	28	58	30	Corridor Arterial		
		Truck	350	28	350	30	Peak Direction	0.75	0.73
			7,000		6,530		Off-Peak Direction	0.50	0.50
					(-6.7%)				
4	Reserved Bus/Pool Lane, Ramp Metering, and Bus By-Pass Lanes; Modest Impacts	On Corridor Freeway:						V/C	RATIO*
								BEFORE	AFTER
			BEFORE		AFTER		Freeway		
		Vehicle Type	VPH	MPH	VPH	MPH	Reserved Lane	1.00	0.31
		Auto	6,290	28	4,440**	28**	Non-Reserved, Peak Dir.		1.12
		Carpool	330	28	500	43	Off-Peak Direction	0.67	0.67
		Bus	28	28	52	43			
		Truck	350	28	280**	28**	Corridor Arterial		
			7,000		5,270**		Peak Direction	0.75	0.72
					(-24.7%**)		Off-Peak Direction	0.50	0.50
		**1,030 vehicles formerly using freeway in peak hours are not able to pass through because of breakdown of flow (i.e., level of service "F") on non-reserved lanes; over-capacity congestion estimated to cause stop-and-go delay over 2.5 minutes on freeway which is not reflected in speed.							
		[Although these travel impacts suggest that an overall worsening of localized air quality would result, the complex nature of the impacts preclude CO concentration impact estimates for this scenario, given the prototype nature of the analysis].							
5	Reserved Bus/Pool Lane, Ramp Metering, and Bus By-Pass Lanes; Favorable Impacts	On Corridor Freeway:						V/C	RATIO*
								BEFORE	AFTER
			BEFORE		AFTER		Freeway		
		Vehicle Type	VPH	MPH	VPH	MPH	Reserved Lane	1.00	0.41
		Auto	6,290	28	4,920	30	Non-Reserved, Peak Dir.		1.00
		Carpool	330	28	640	43	Off-Peak Direction	0.67	0.67
		Bus	28	28	66	43			
		Truck	350	28	350	30	Corridor Arterial		
			7,000		5,980		Peak Direction	0.75	0.68
					(-14.6%)		Off-Peak Direction	0.50	0.50

*V/C RATIO IS THE RATIO OF VEHICLE VOLUME TRAVEL DEMAND TO FACILITY CAPACITY (LEVEL OF SERVICE "E", 1965 HIGHWAY CAPACITY MANUAL).

EXHIBIT 10

MAJOR TRAVEL IMPACTS FOR LOCALIZED SCENARIOS (Cont'd)

PROTOTYPE SCENARIO		A.M. PEAK HOUR TRAVEL CONDITIONS IN CO IMPACT AREA					
ID No.	TITLE	PEAK DIRECTION VEHICLE VOLUMES AND AVERAGE SPEEDS ON PRIMARY CORRIDOR FACILITY					
			BEFORE		AFTER		
		Vehicle Type	VPH	MPH	VPH	MPH	
6	Contraflow Freeway Lane Reserved for Buses; Favorable Impacts	On Corridor Freeway:					
		Auto	4,720	20	4,520	20	
		Carpool	250	20	240	20	
		Bus	10	20	20	40	
		Truck	200	20	200	20	
			5,250		5,080 (-3.3%)		
7	Contraflow Bus Lane, Expanded Express Bus Service, and Park-and-Ride Lots; Favorable Impacts	On Corridor Freeway:					
		Auto	4,720	20	4,280	20	
		Carpool	250	20	220	20	
		Bus	10	20	40	40	
		Truck	200	20	260	20	
			5,250		4,810 (-8.4%)		
8	Contraflow Bus Lane, Expanded Service, and Lots; Assuming 70%/30% Directional Split; Favorable Impacts	On Corridor Freeway:					
		SAME AS SCENARIO 7	BEFORE		AFTER		
		[Only the off-peak freeway volumes were adjusted to achieve the 70%/30% instead of the usual 60%/40% directional split. This is reflected in a lower "before" V/C ratio for the off-peak direction in column to the right].					
9	Reserved Arterial Median Lane for Express Buses; Favorable Impacts	On C[illegible]					
		Vehi[illegible]	VPH	MPH	VPH	MPH	
		Auto	2,020	15	1,440	15	
		Carpool	110	15	80	15	
		Local Bus	15	10	15	10	
		Express Bus	0	-	20	23	
		Truck	110	15	110	15	
			2,250		1,670 (-25.8%)		
10	Contraflow Curb Lane for Local Buses on Pair of One-Way Arterials; Favorable Impacts	On Arterial Lanes in In-Bound Direction:					
		Auto	2,660	15	2,450	16	
		Carpool	140	15	130	16	
		Local Bus	40	10	40**	15**	
		Express Bus	5	15	5	16	
		Truck	150	15	150	16	
			3,000		2,780 (-7.3%)		
		**On contraflow bus lane of out-bound arterial.					

ID No.	VOLUME TO CAPACITY RATIO CONGESTION LEVELS*	V/C RATIO* BEFORE	V/C RATIO* AFTER
6	Freeway		
	Peak Direction	1.00	0.96
	Reserved Contraflow Lane	0.67	0.02
	Non-Reserved, Off-Peak Dir.		1.00
	Corridor Arterial		
	Peak Direction	0.75	0.74
	Off-Peak Direction	0.50	0.50
7	Freeway		
	Peak Direction	1.00	0.91
	Reserved Contraflow Lane	0.67	0.04
	Non-Reserved, Off-Peak Dir.		1.00
	Corridor Arterial		
	Peak Direction	0.75	0.73
	Off-Peak Direction	0.50	0.50
8	Freeway		
	Peak Direction	1.00	0.91
	Reserved Contraflow Lane	0.43	0.04
	Non-Reserved, Off-Peak Dir.		0.64
	Corridor Arterial		
	Peak Direction	0.75	0.73
	Off-Peak Direction	0.50	0.50
9	Arterial		
	Non-Reserved, Peak Direction	0.94	1.03
	Reserved Median Lane		0.05
	Off-Peak Direction	0.94	0.94
10	Arterials		
	Peak Direction	0.94	0.85
	Reserved Contraflow Lane	0.83	0.09
	Non-Reserved, Off-Peak Dir.		0.83

*V/C RATIO IS THE RATIO OF VEHICLE VOLUME TRAVEL DEMAND TO FACILITY CAPACITY (LEVEL OF SERVICE "E", 1965 HIGHWAY CAPACITY MANUAL).

This has both air quality and obvious political feasibility implications. However, in scenario 8, where a more extreme directional split of 70 percent/30 percent is assumed (instead of 60 percent/40 percent), the off-peak direction congestion impacts are reduced, illustrating the importance of prevailing travel condition details in determining the air quality impacts.

In the absence of details on highway geometrics, topography, vegetation, etc., it is difficult to quantitatively estimate the noise impacts for the localized scenarios. However, the overall peak hour vehicle volume reductions reported in Exhibit 10 are significant (as high as a 26 percent reduction for scenario 9), suggesting the potential for noticeable highway noise reductions. Given equal volumes and volume changes, the noise impacts from arterials are likely to be more significant than those from freeways since freeways frequently are separated from population concentrations by greater distances, have better acoustical insulation, and have less vehicular acceleration and deceleration. However, the higher operating speeds on freeways do tend to counterbalance these factors to some extent.

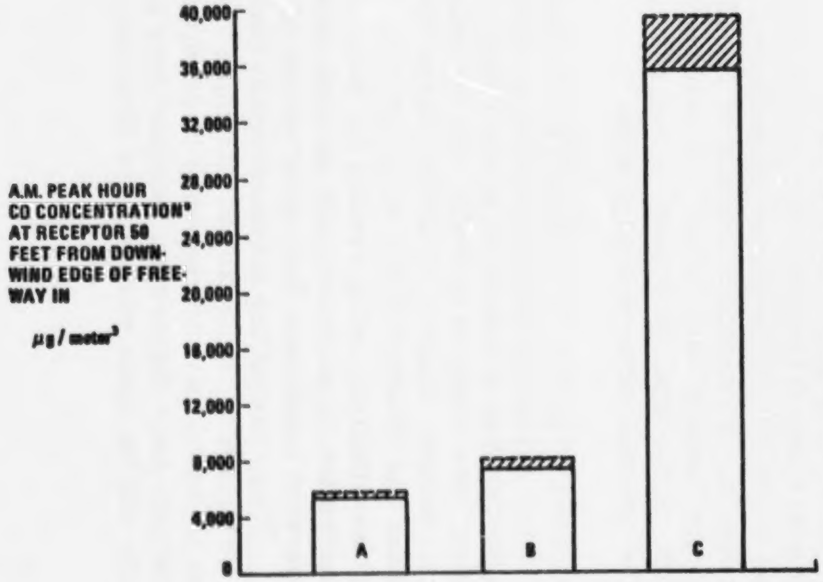
Localized CO Concentration Impacts

Based on the above travel impacts, line source emission strengths on all corridor facilities in the CO concentration impact area were calculated for each localized scenario. An expanded version of the EPA HIWAY model was then used to estimate "before" and "after" CO concentrations associated with highway traffic on the affected prototype facilities for 121 receptor grid points covering the one mile square impact area.

For each localized scenario, CO concentration impact estimates were made for each of three prototype meteorological conditions: (a) typical good dispersion (this general type of condition is most likely to prevail); (b) typical poor dispersion (less likely to prevail); and (c) extremely poor dispersion (least likely to occur). Exhibit 11 defines these three prototype meteorological conditions and illustrates the variation in CO concentrations over the three different assumptions using results for scenario 2. Total concentrations and concentration impacts are both several times higher under extremely poor dispersion conditions than under either of the two other prototype conditions. Thus, prevailing meteorological conditions are a very critical factor in determining the localized CO impact actually realized. However, because of the relative infrequency of conditions similar to those specified for extremely poor dispersion, comparisons among scenarios in subsequent exhibits will be made with only the first two meteorological conditions.

EXHIBIT 11

ILLUSTRATING THE IMPACT OF PREVAILING METEOROLOGICAL CONDITIONS ON A.M. PEAK HOUR CO CONCENTRATIONS*



ASSUMED METEOROLOGICAL CONDITIONS

CODE	A	B	C
LABEL	TYPICAL GOOD DISPERSION	TYPICAL POOR DISPERSION	EXTREMELY POOR DISPERSION
WIND DIRECTION †	PERPENDICULAR TO PRIMARY CORRIDOR FACILITY	PERPENDICULAR TO PRIMARY CORRIDOR FACILITY	20° OFF OF PARALLEL TO PRIMARY CORRIDOR FACILITY
WIND SPEED	4 m/sec.	4 m/sec.	2 m/sec.
TEMPERATURE	75°F	32°F	32°F
STABILITY CLASS	D (Neutral)	E (Stable)	F (Very Stable)
MIXING DEPTH	700 meters	400 meters	200 meters

*The illustrative CO concentrations displayed in this exhibit are for scenario 2. The concentrations are based on vehicular emissions from affected freeway and arterial only and assume uninterrupted traffic flow conditions.

As mentioned above, CO concentration estimates were made using an 11 x 11 grid of receptor points covering the impact area. Exhibit 12 illustrates the spatial variation in CO concentrations around the prototype freeway and arterial along cross-sectional profile lines at each end of the impact area, again for scenario 2. Along both cross-sectional profiles, CO concentrations peak just downwind from the freeway. Concentrations from the affected facilities are substantially higher in this area than at any other location along the profile line. Concentrations drop off to less than one-half their maximum receptor value at a distance 0.1 mile further downwind.

As between the two cross-sectional profiles, maximum concentration is slightly higher at the end where the freeway and arterial center lines are separated by only one-quarter mile. However, the area of significant concentration levels is also significantly compressed. It should be emphasized that these concentration estimates do not include "background" CO concentrations from stationary sources and highway facilities not directly affected by the scenario strategy, and do not reflect CO concentrations at distances less than 50 feet from the edge of the roadway. The effects of these factors on CO concentrations are illustrated later in this section.

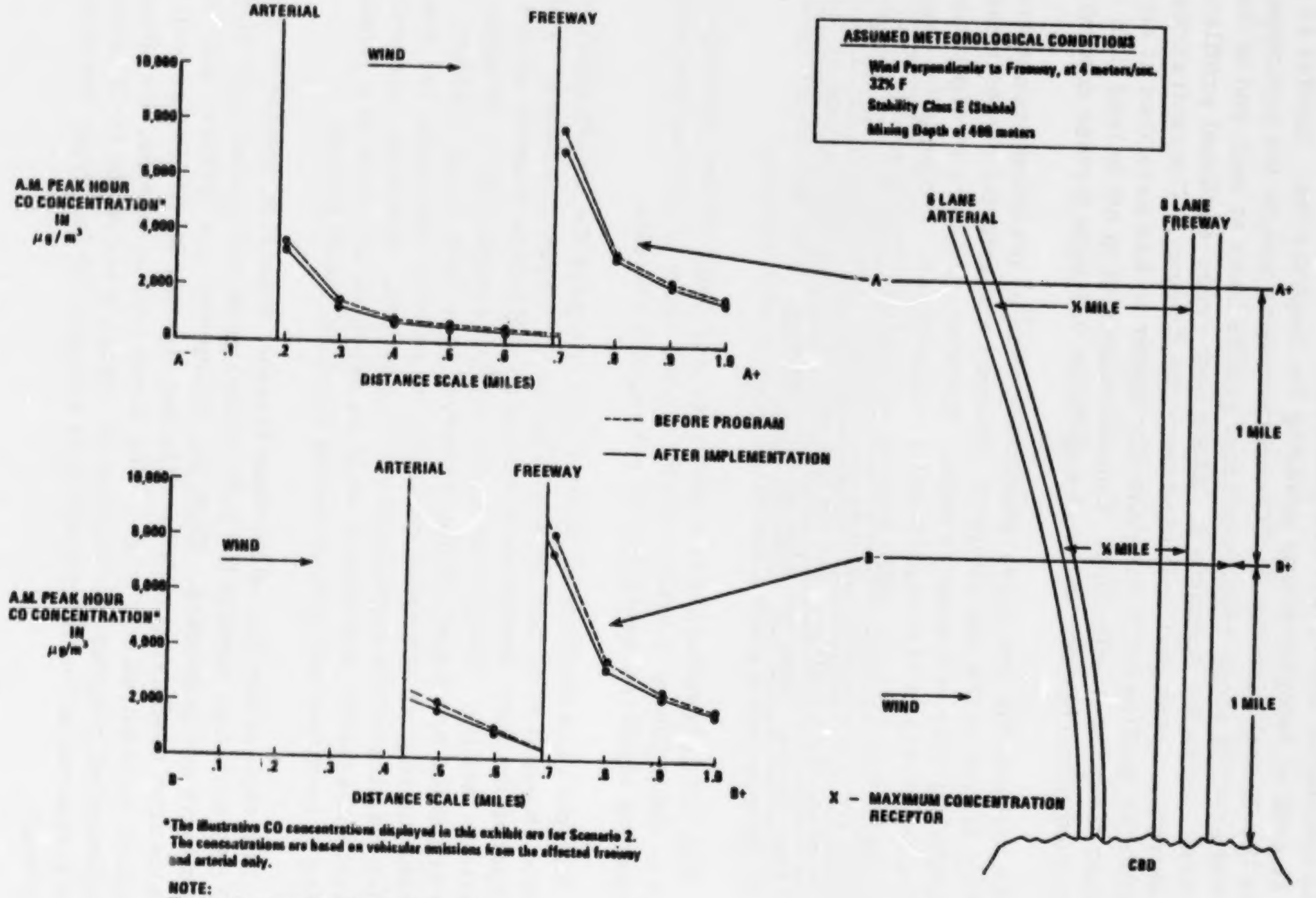
The CO concentration at a grid receptor point 50 feet downwind from the edge of the primary corridor facility under study is used as the basis for comparing localized scenarios in subsequent exhibits.

Exhibit 13 is the first of three which compare the localized CO concentration impacts of scenarios with similar prototype conditions. Exhibit 13 compares the four scenarios involving an eight-lane freeway as the primary corridor facility. Because of travel impact complications resulting from the projected breakdown of non-reserved lane flow on the freeway, CO concentration impact estimates could not be reliably estimated for scenario 4, which was therefore excluded from this exhibit. However, the projected travel impacts for scenario 4 could be expected to result in a general worsening of localized air quality during the A.M. peak period.

For each of the four eight-lane freeway scenarios treated in Exhibit 13, CO concentration results for both typical good and typical poor dispersion conditions are presented. Each bar illustrates the "before" and "after" concentrations associated with the affected highway facilities, as well as the implicit concentration change. For these four scenarios, the impact of the implemented program or strategy is always a reduction in CO concentration (as measured at the referenced grid receptor 50 feet from the edge of the freeway.

EXHIBIT 12

ILLUSTRATING THE SPATIAL VARIATION IN A.M. PEAK HOUR CO CONCENTRATION AROUND PROTOTYPE HIGHWAY FACILITIES*

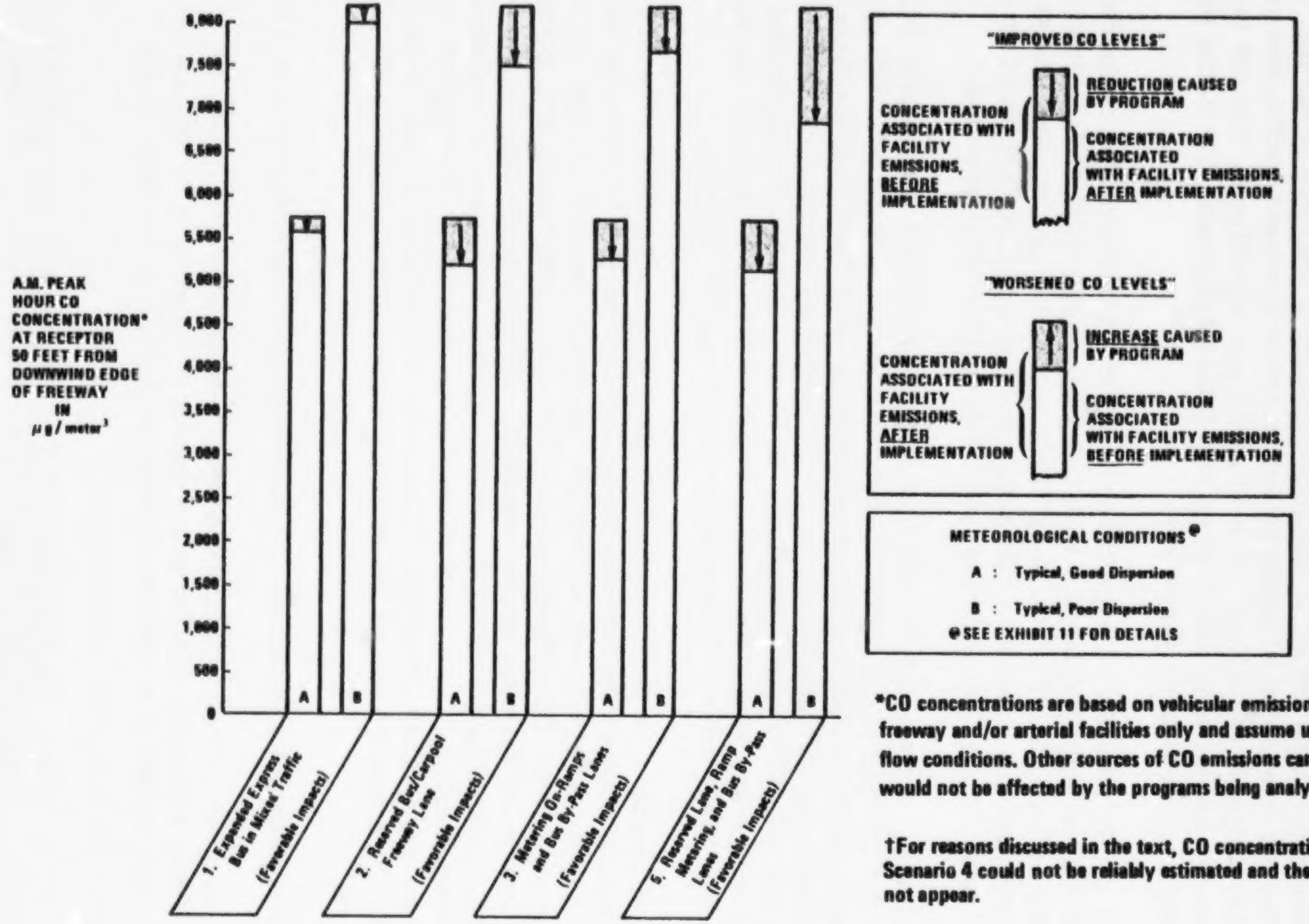


*The illustrative CO concentrations displayed in this exhibit are for Scenario 2. The concentrations are based on vehicular emissions from the affected freeway and arterial only.

NOTE:
The above line segment plots connect discrete receptor concentration values (at 0.1 mile intervals) and are not intended to accurately portray concentrations between these points.

EXHIBIT 13

LOCALIZED CO CONCENTRATION IMPACTS* : COMPARISON OF SCENARIOS INVOLVING 8 LANE FREEWAY†



*CO concentrations are based on vehicular emissions from affected freeway and/or arterial facilities only and assume uninterrupted traffic flow conditions. Other sources of CO emissions can be substantial, but would not be affected by the programs being analyzed.

†For reasons discussed in the text, CO concentration estimates for Scenario 4 could not be reliably estimated and therefore do not appear.

The greatest reduction in CO concentration is achieved by scenario 5, the most ambitious combination freeway program, with a reduction in excess of 10 percent of the initial highway-related concentration. The smallest reduction is achieved by scenario 1 (approximately 2.5 percent relative to initial concentration), which is the least ambitious freeway program, calling only for the expansion of express bus service in mixed traffic and provision of park-and-ride facilities. The impacts are significant, but not large on a percentage basis, especially when one adds background CO to the base highway concentrations displayed.

As illustrated by the significantly different outcome for scenario 4 (which was simply scenario 5 with more modest modal shift assumptions), one should be aware that the magnitude and even sign of these illustrative prototype impact estimates can easily vary from those achieved in a specific actual application, depending on the factors already discussed.

As noted above, the CO concentrations presented in Exhibits 13, 15 and 16 do not include background CO concentrations. Using a 5,700 $\mu g/m^3$(5 ppm)[1] background CO concentration in conjunction with the CO concentrations in these exhibits indicate that none of the scenarios violates the 1-hour NAAQS for CO of 40,000 $\mu g/m^3$ (35 ppm). However, Exhibit 14 illustrates that selected scenarios which do not violate the 1-hour CO standard can approach or exceed the 8-hour CO NAAQS of 10,000 $\mu g/m^3$ (9 ppm).

For example, a peak 1-hour CO concentration of approximately 8,000 $\mu g/m^3$ (for vehicle emissions only) is shown for the before condition for scenario 5 in Exhibit 13. This corresponds to an approximately 11,000 $\mu g/m^3$ maximum 8-hour CO concentration (including background) at a distance of 25 feet from the edge of the roadway, which exceeds the 8-hour NAAQS for CO. After implementing the transportation measures in scenario 5, the maximum 8-hour CO concentration is estimated at 10,200 $\mu g/m^3$ at 25 feet from the edge of the roadway. The latter concentration just exceeds the 8-hour CO standard and represents an important reduction in CO concentrations.

This example and Exhibit 14 illustrate the following important points:

. In those scenarios in which peak 1-hour CO concentrations from vehicular traffic alone approach or exceed 7,000 $\mu g/m^3$ (at a distance of approximately 50 feet from the edge of the

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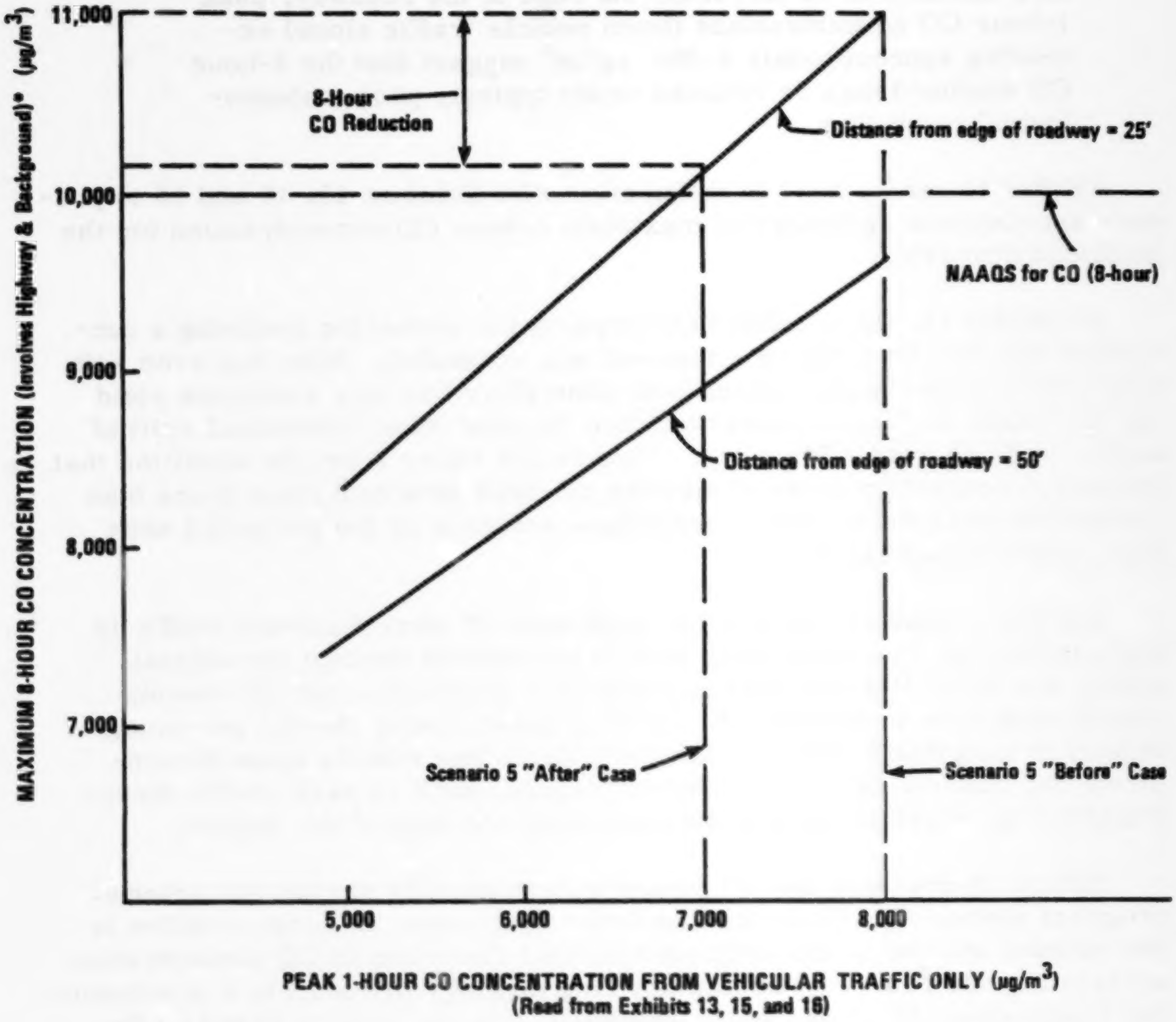
[1] GCA Corporation. Identification of Localized Violation of Carbon Monoxide Standards - Volume I: Guidelines (Draft Final Report). Prepared for EPA-Region I office, November 1975, pg. II-13.

EXHIBIT 14

RELATIONSHIP BETWEEN MAXIMUM 8-HOUR AND PEAK 1-HOUR CO CONCENTRATIONS FOR TYPICAL, POOR DISPERSION CONDITIONS*



*** Assumptions:**

1. **Concentrations reflect typical, poor dispersion conditions.**
2. **A background CO concentration of 5,700 $\mu g/m^3$ (5 ppm) is assumed driving the peak 1-hour.**
3. **A 0.7 ratio of the maximum 8-hour to peak 1-hour CO concentration is assumed.**
4. **A factor of 1.25 was used to convert CO concentrations (from vehicular volumes only) at 50 feet from the edge of the roadway to CO concentrations at 25 feet from the edge of the roadway.**
5. **Estimated CO concentrations assume uninterrupted traffic flow conditions.**

roadway), the 8-hour NAAQS for CO may be violated under typical, poor dispersion conditions at locations approximately 25 feet from the edge of the roadway.

- At a distance of 50 feet from the edge of the roadway, peak 1-hour CO concentrations (from vehicle traffic alone) exceeding approximately 8,000 $\mu g/m^3$ suggest that the 8-hour CO standard may be violated under typical, poor meteorological conditions.

Exhibit 14 can be used in conjunction with Exhibits 13, 15 and 16 to prepare approximate estimates of maximum 8-hour CO concentrations for the localized scenarios.

In Exhibit 15, the localized CO impacts for scenarios involving a contraflow bus lane on a six-lane freeway are presented. Note that even with a favorable impact assumption, both contraflow bus lane scenarios yield net increases in CO concentration when the peak hour directional split of traffic is 60 percent/40 percent. This result stems from the condition that increased congestion in the remaining off-peak direction lanes more than counterbalances the emission reductions achieved by the projected shift from autos to express bus.

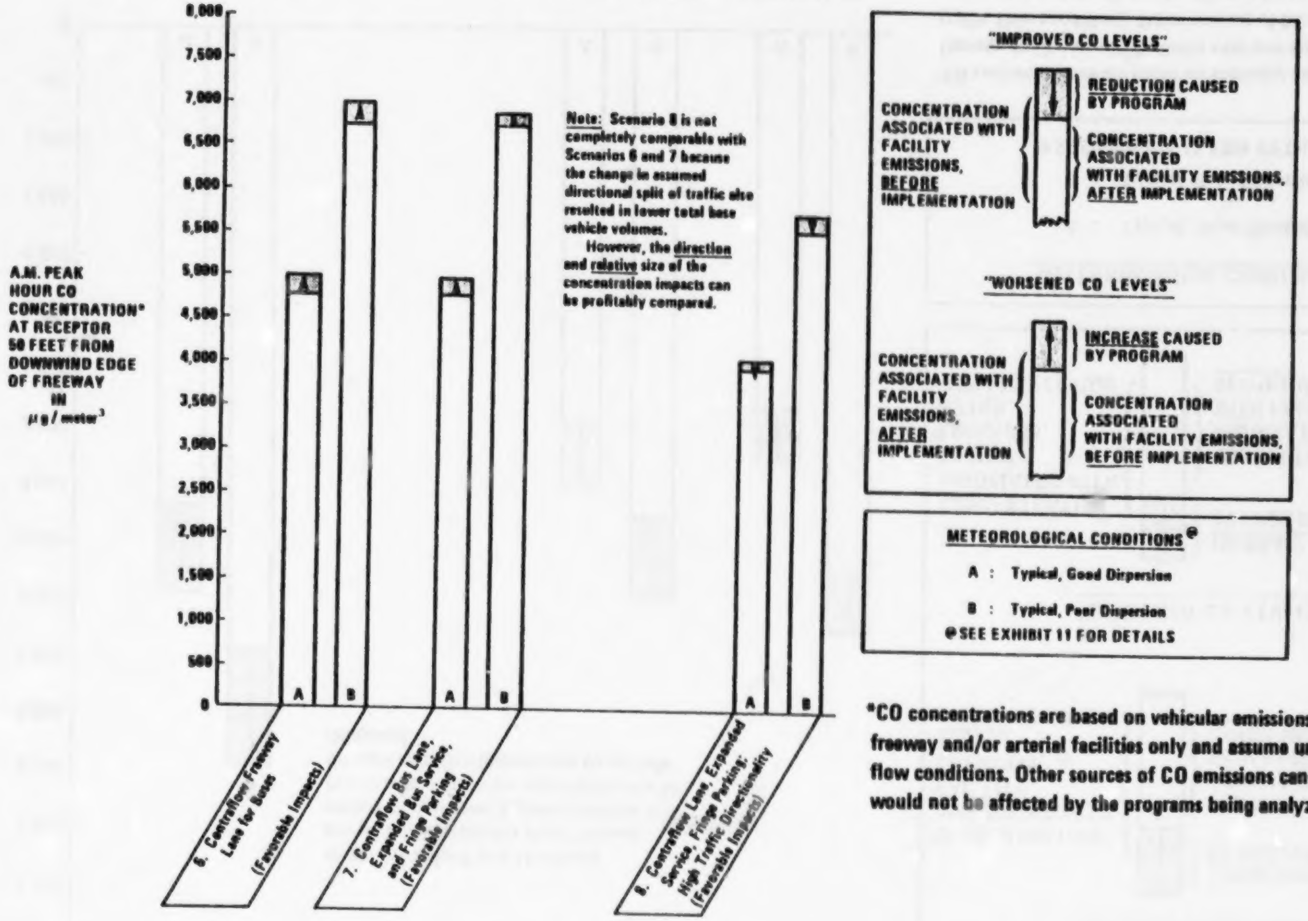
However, when the base A.M. peak hour off-peak direction traffic is assumed lighter (corresponding to a 70 percent/30 percent directional split), the same strategy used in scenario 7 produces a net CO concentration reduction in scenario 8. In all of these cases, the net percentage impact is less than 5 percent, but these prototype results again demonstrate the importance of site-specific details, such as peak traffic directionality, in determining both the magnitude and sign of the impact.

Exhibit 16 presents the CO concentration impacts for the two arterial program scenarios. While the absolute changes are not large relative to the national standard, the estimated percent reduction in CO concentration achieved by the reserved median bus lane strategy in scenario 9 is substantial (approximately 15 percent). However, this scenario is based on the assumption of a total (local and express) bus modal split of 40 percent in the corridor, which is reasonable, but may not be easily achieved in some areas.

The results for the contraflow curb bus lane are mixed. Since a pair of one-way arterials is involved, two maximum receptor concentration points are present. In this case, the increase in concentration adjacent to the arterial with the contraflow lane (caused by increased congestion in the

EXHIBIT 15

LOCALIZED CO CONCENTRATION IMPACTS* : COMPARISON OF SCENARIOS INVOLVING CONTRAFLOW LANE ON 6 LANE FREEWAY



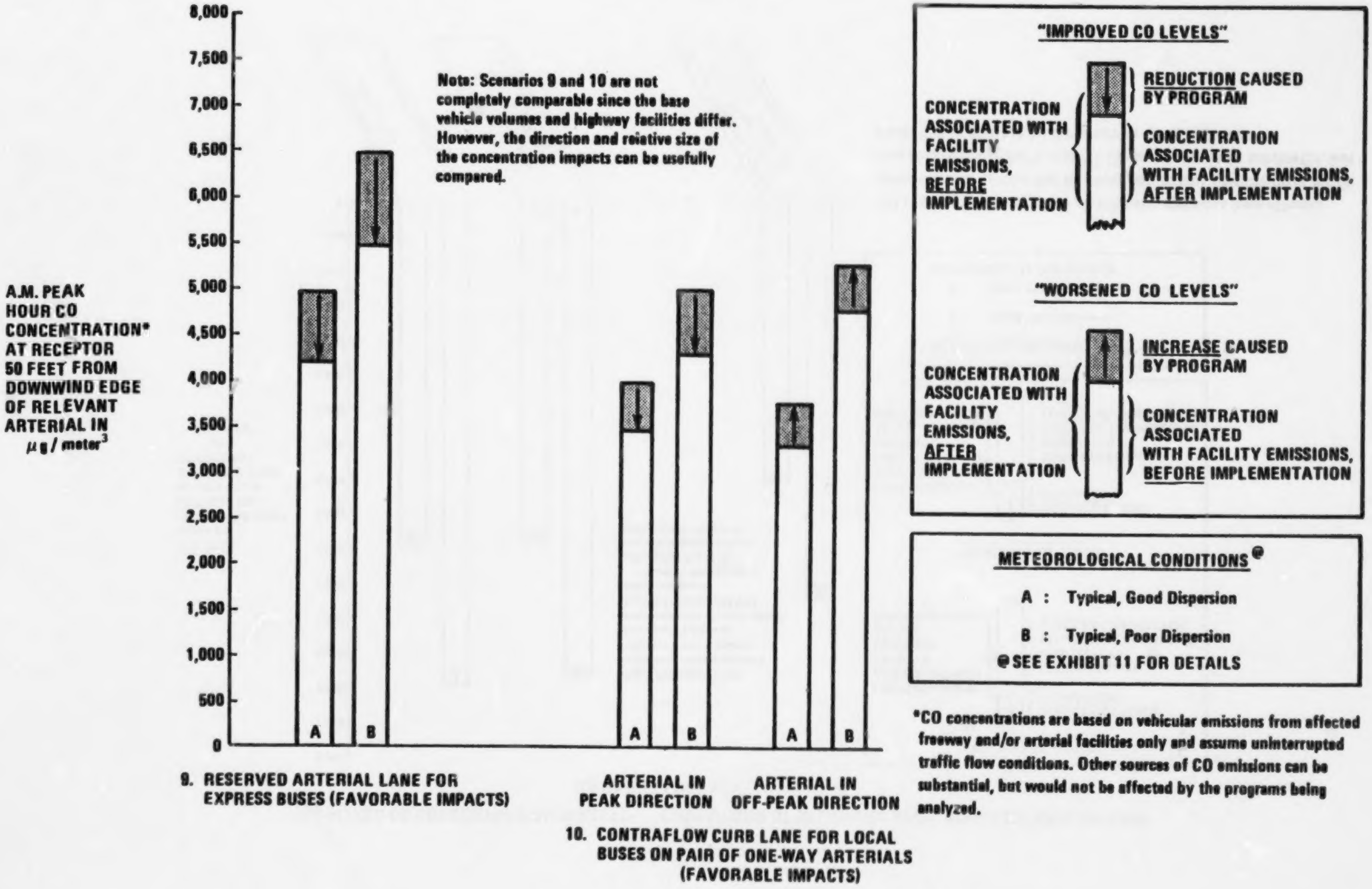
Note: Scenario 8 is not completely comparable with Scenarios 6 and 7 because the change in assumed directional split of traffic also resulted in lower total base vehicle volumes.

However, the direction and relative size of the concentration impacts can be profitably compared.

*CO concentrations are based on vehicular emissions from affected freeway and/or arterial facilities only and assume uninterrupted traffic flow conditions. Other sources of CO emissions can be substantial, but would not be affected by the programs being analyzed.

EXHIBIT 16

LOCALIZED CO CONCENTRATION IMPACTS* : COMPARISON OF SCENARIOS INVOLVING RADIAL ARTERIALS AS THE PRIMARY FACILITY



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*CO concentrations are based on vehicular emissions from affected freeway and/or arterial facilities only and assume uninterrupted traffic flow conditions. Other sources of CO emissions can be substantial, but would not be affected by the programs being analyzed.

remaining off-peak lanes) comes close to matching the decrease in concentration adjacent to the peak direction arterial (caused by the projected shift from autos to local bus). The end result is to increase congestion adjacent to the off-peak arterial to a level higher than that originally around the peak direction facility and to reduce the congestion adjacent to the peak direction facility to a level below that originally around the off-peak arterial. However, as illustrated in Exhibit 15, this particular result could have been substantially different if a more extreme directional split of traffic on the two arterials had been assumed.

Capital and Operating Costs

Exhibit 17 presents the estimated capital and annual operating costs for the localized scenarios. Appendix B presents the unit costs used in the development of the capital and annual costs. The costs presented in Exhibit 17 are order of magnitude estimates based on costs published in the literature.

The largest individual cost item for all of the scenarios is for improvements to express bus service. Generally, the geographic coverage and the frequenCy of express bus service were assumed to increase significantly in order to complement the reserved HOV lanes and attract large numbers of auto travelers. The annual cost of bus service shown in Exhibit 17 represents the incremental cost of providing bus service above that assumed in the base case (i.e., "before" case).

The costs of implementing ramp metering and park-and-ride facilities are also significant. With regard to the cost of park-and-ride lots, two conditions are assumed. If use can be made of existing parking facilities at shopping centers or other locations, the capital cost of such facilities would be negligible. However, such arrangements may not be feasible in many locations, and the full capital cost of constructing the park-and-ride facilities is also presented (the two capital cost values are separated by a slash in Exhibit 17). For both of these conditions, the cost of operating and maintaining the park-and-ride lots is assumed to be a public cost.

Based on analyses of express bus operations in Minneapolis (i.e., I-35W projects) and Seattle (i.e., Blue Streak project), annual operating revenues may only offset approximately 50 percent to 66 percent of the annual operating and maintenance costs of express bus service shown in Exhibit 17. Consequently, sizeable annual operating subsidies may be required to operate express bus services such as those assumed in the localized scenarios. If fare reductions are implemented, the subsidy requirements are likely to be even more significant.

EXHIBIT 17

CAPITAL AND ANNUAL OPERATING AND MAINTENANCE COSTS FOR LOCALIZED SCENARIOS

PROTOTYPE SCENARIO		COSTS (IN THOUSANDS OF 1976 DOLLARS)		
ID NO.	TITLE	ITEM	CAPITAL	ANNUAL OPERATING AND MAINTENANCE
1	Expanded Express Bus Service in Mixed Freeway Traffic; Favorable Impacts	Park and Ride Lots Express Express Bus Service	$0/1,620 3,168 3,168/4,788	$248 1,199@ 1,447
2	Freeway Lane Reserved for Buses and Carpools; Favorable Impacts	Reserved Lane Park and Ride Lots Express Bus Service	100 0/1,620 3,630 3,720/5,350	220 248 1,371@ 1,839
3	Ramp Metering and Bus By-Pass Lanes; Favorable Impacts	Ramp Metering Bus By-Pass Ramps Express Bus Service Park and Ride Lots	1,134 460 3,630 0/1,620 5,224/6,844	84 — 1,371@ 248 1,703
4	Reserved Bus/Pool Lane, Ramp Metering, and Bus By-Pass Lanes; Model Impacts	Ramp Metering Reserved Lane Bus By-Pass Ramps Express Bus Service Park and Ride Lots	1,134 100 460 3,168 0/1,620 4,862/6,482	84 220 — 1,199@ 248 1,751@

@ This represents the incremental annual operating and maintenance costs of providing bus service beyond existing bus service.

Note: The cost projections have been prepared on the basis of the assumptions set forth in Appendix B. The actual costs of the above strategies will depend upon the specific setting in which they are implemented.

EXHIBIT 17 (Continued)

PROTOTYPE SCENARIO		COSTS (IN THOUSANDS OF 1976 DOLLARS)		
ID NO.	TITLE	ITEM	CAPITAL	ANNUAL OPERATING AND MAINTENANCE
5	Reserved Bus/Pool Lane, Ramp Metering and Bus By-Pass Lanes; Favorable Impacts	Ramp Metering	1,134	84
		Reserved Lane	100	220
		Bus By-Pass Ramps	460	—
		Express Bus Service	4,554	1,714@
		Park and Ride Lots	0/1,620	248
			6,248/7,868	2,286
6	Contra-Flow Freeway Lane Reserved for Buses; Favorable Impacts	Contra-Flow Lane	500	220
		Express Bus Service	462	321@
			962	541
7	Contraflow Bus Land Expanded Express Service, and Park and Ride Lots; Favorable Impacts	Contra-Flow Lane	500	220
		Express Bus Service	3,168	1,350@
		Park and Ride Lot	0/1,620	248
			3,668/5,288	1,818
8	Contra-Flow Bus Lane Expanded Service, and Lots Assuming 70%/30% Directional Split; Favorable Impacts	Contra-Flow Lane	500	220
		Express Bus Service	3,168	1,350@
		Park and Ride Lot	0/1,620	248
			3,663/5,288	1,818
9	Reserved Arterial Median Lane for Express Buses; Favorable Impacts	Reserved Median Lane	1,350	29
		Express Bus Service	2,244	1,029@
		Park and Ride Lot	0/540	82
			3,594/4,134	1,130
10	Contraflow Curb Lane for Local Buses on Pair of One-Way Arterials; Favorable Impacts	Contra-Flow Curb Lane	6	–
		Bus Service	462	123
			468	123

Economic Impacts

The economic impacts of the localized scenarios are likely to be small. There is little evidence in the literature which suggests that any of the localized transportation measures considered have any measurable effects on employment, retail sales, or related economic factors.

Economic benefits in the form of travel time and travel cost savings are likely to be realized by travelers attracted to transit and ride-sharing programs. For example, a 10 mile trip on a reserved freeway lane is estimated to yield a 6 to 8 minute reduction in travel time as compared with the same trip made on the non-reserved freeway lanes. Similarly, significant travel cost savings in the form of reduced gasoline, insurance, maintenance, and parking costs can be achieved by those travelers who diverted from single occupant vehicles to either transit or carpools/vanpools

The combination of expanded bus service and reserved freeway or arterial lanes will improve the accessibility to the CBD in the affected corridors. This may induce non-work trips to the CBD even if the express bus service is primarily intended for peak period travelers.

REGIONAL SCENARIO IMPACT ESTIMATES

In this section, the following impacts are presented and discussed for each of the 10 regional scenarios:

- travel impacts;
- regional HC, NO , and CO emission impacts;
- regional fuel consumption impacts;
- capital and operating costs; and
- economic impacts.

Travel Impacts

As for the localized scenarios, estimation of travel impacts is also a critical first step in the analysis of the regional scenarios. For the regional scenarios, travel impacts are expressed in terms of changes in regional weekday vehicle miles travelled (VMT). For the purpose of estimating regional emission and fuel consumption impacts, the VMT changes are allocated to road type, vehicle type, and average speed groups.

Exhibit 18 summarizes the travel impacts for the 10 regional scenarios. With the exception of the first scenario, all pertain to the large prototype region (in the 1,000,000+ SMSA population range). Scenario 11 is set in the medium-sized prototype region (500,000-1,000,000 SMSA population range). For each regional scenario, Exhibit 18 presents the absolute "before" and "after" regional weekday VMT as well as the percent change this represents. In addition, the VMT change is also expressed as a percent of regional work trip VMT and (where appropriate) as a percent of the total VMT estimated to be directly affected by the scenario program. These last two percentage impact values are intended to provide a better indication of the strategy impact within the affected travel market (which can be substantially smaller than total regional travel).

The following major observations are relevant:

- although the absolute quantities are different, the percentage changes in regional VMT for the carpool/vanpool program applied in both the medium-sized and large prototype regions are essentially the same;
- the carpool/vanpool program, focused on major employers, is generally several times more effective in reducing regional VMT than multiple areawide application of the corridor strategies, primarily because it has a larger affected travel market;
- carpool/vanpool programs can be combined with multiple applications or radial corridor strategies with little competitive overlap of individual impacts, since the two affected travel markets are largely mutually exclusive when the programs are correctly implemented; and

Regional HC, NO_x, and CO Emission Impacts

Using the latest EPA mobile source emission factors for 1978,[1] base condition weekday regional highway emissions were calculated for the medium-sized and large prototype urban regions. Changes in weekday regional highway emissions were calculated for each of the 10 regional scenarios. Regional emission estimates were made for hydrocarbons (HC), nitrogen oxides (NO_x), and carbon monoxide (CO).

All of the emission estimates were made for the standard reference conditions of 75° F and 75 grains/b. absolute humidity. However, a limited

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[1] As of February 1978.

EXHIBIT 18

MAJOR TRAVEL IMPACTS FOR REGIONAL SCENARIOS

PROTOTYPE SCENARIO		WEEKDAY REGIONAL VMT**		PERCENT CHANGE IN TOTAL REGIONAL VMT	PERCENT CHANGE RELATIVE TO WORK TRIP REGIONAL VMT†	PERCENT CHANGE RELATIVE TO "AFFECTED" REGIONAL VMT@
ID No.	TITLE*	BEFORE PROGRAM IMPLEMENTATION	AFTER PROGRAM IMPLEMENTATION			
11	Carpool/Vanpool Program, Medium Size City; Favorable Impacts	9,846,000	9,690,000	-1.6%	-5.3%	N.A.
12	Carpool/Vanpool Program, Large City; Favorable Impacts	43,946,000	43,287,000	-1.5%	-5.0%	N.A.
13	Reserved Bus/Pool Lanes, Ramp Metering, and Bus By-Pass Lanes on All Appropriate Freeways; Modest Impacts	43,946,000	43,836,000	-0.25%	-0.8%	-6.1%
14	Reserved Bus/Pool Lanes, Ramp Metering, and Bus By-Pass Lanes on All Appropriate Freeways; Favorable Impacts	43,946,000	43,750,000	-0.44%	-1.5%	-10.8%
15	Reserved Median Lane for Express Buses on Appropriate Radial Arterials; Modest Impacts	43,946,000	43,846,000	-0.23%	-0.8%	-13.8%
16	Reserved Median Lane for Express Buses on Appropriate Radial Arterials; Favorable Impacts	43,946,000	43,778,000	-0.38%	-1.3%	-23.2%
17	Carpool/Vanpool Program and Freeway Reserved Lanes; Modest Impacts	43,946,000	43,512,000	-1.0%	-3.3%	N.A.
18	Carpool/Vanpool Program and Freeway Reserved Lanes; Favorable Impacts	43,946,000	43,110,000	-1.9%	-6.3%	N.A.
19	Carpool/Vanpool Program, Reserved Lanes, Ramp Metering, and Bus By-Pass Lanes; Modest Impacts	43,946,000	43,506,000	-1.0%	-3.3%	N.A.
20	Carpool/Vanpool Program, Reserved Lanes, Ramp Metering, and Bus By-Pass Lanes; Favorable Impacts	43,946,000	43,092,000	-1.9%	-6.5%	N.A.

*All scenarios except for #11 are for a "large" city (1,000,000 + SMSA population). Scenario 11 is set in a "medium size" city (500,000 - 1,000,000 SMSA population).

**Vehicle miles travelled on an average workday in the region

†Work trip VMT is estimated at 30% of total weekday regional VMT.

@"Affected" Regional VMT. For Scenarios 13 and 14: Consists of peak period, peak direction VMT estimated to be on: (a) radial freeway segments having the reserved lane and (b) major radial arterials within the affected freeway corridors. For Scenarios 15 and 16: Peak period, peak direction VMT estimated to be on roughly 72 miles of major radial arterials with a reserved median lane.

number of estimates were also made for 32° F and absolute humidity of 15 grains/lbs. for comparison purposes. Exhibit 19 illustrates the variation in regional emissions associated with these two different temperature and humidity assumptions. While emissions are higher at the lower temperature, it should be pointed out that photochemical oxidant problems are typically worst during periods of warm weather when atmospheric conditions favor the formation and concentration of oxidants near the surface.

Exhibit 20 presents the estimated emissions and fuel consumption reduction impacts of a carpool/vanpool program for both the medium-sized and large prototype regions. As expected, the absolute quantities are proportionally higher for the large region, but the percentage impacts are virtually identical for the two regions, without a consistent advantage to either across the four impact indices. All subsequent impact comparisons among regional scenario strategies and programs will be based on the large prototype region as the standard.

Exhibits 21 through 23 compare the nine regional scenarios for the large prototype region in terms of their HC, NO_x, and CO emission impacts, respectively. Regional HC and NO_x emissions are primary inputs to the process which produces photochemical oxidants in urban areas. Regional CO emissions are of less significance since CO is primarily a localized air quality concern.

Overall, the emissions impacts tend to reflect the percentage VMT impacts.[1] This is most true for NO_x emissions. However, the speed sensitivity of the most recent EPA emission factors for HC and, even more so, CO have resulted in percentage change emission impacts for some scenarios which are significantly different from the corresponding VMT impacts. As illustrated in Exhibits 21 and 23, some of the strategies involving reserved lanes on freeways and arterials are estimated to yield increases in HC and CO emissions, respectively, despite the achievement of overall VMT reductions for these same strategies.

Because of the sensitivity of HC and CO emissions to vehicle speed, the shifts of VMT to slower average speed classes (estimated to result from

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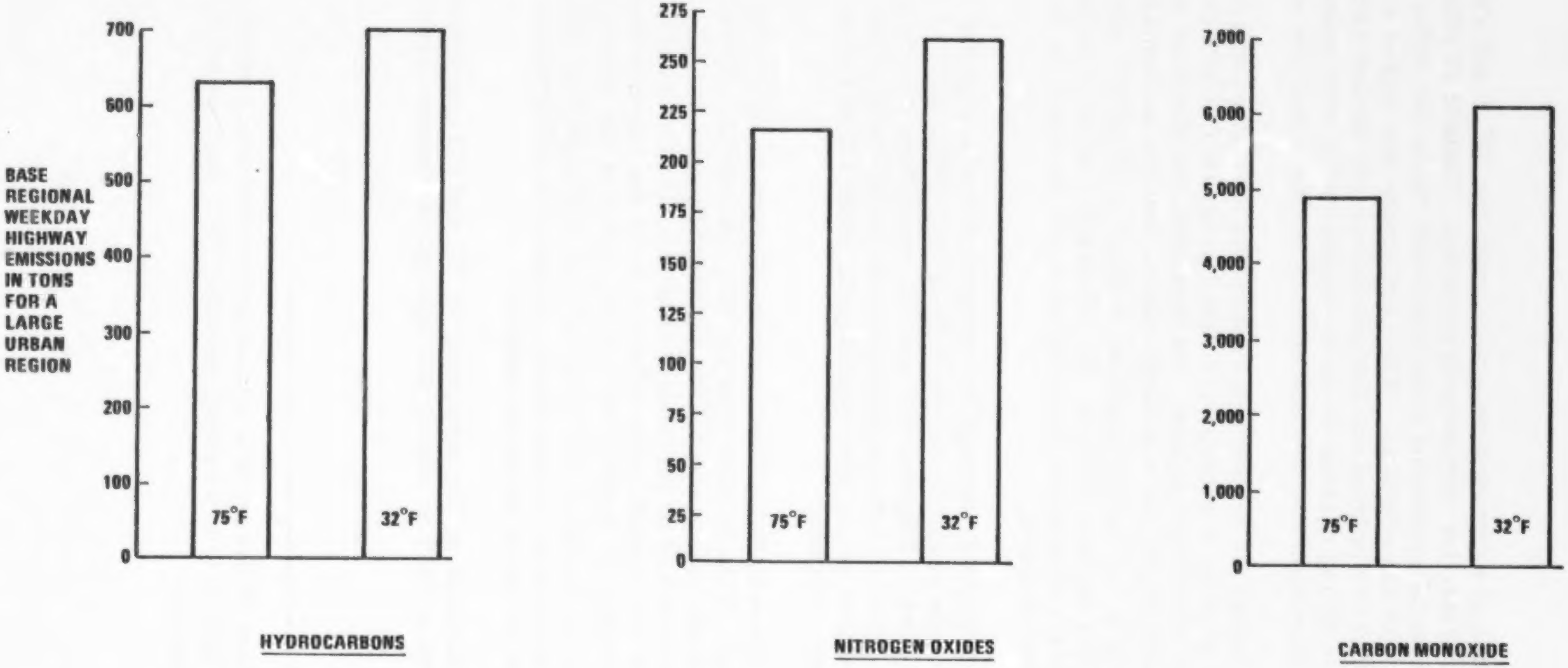
[1] Exhibit 28 presents a tabular impact summary which includes the percentage changes in total regional weekday VMT associated with each of the regional scenarios.

EXHIBIT 19

ILLUSTRATING THE EFFECTS OF TEMPERATURE ON REGIONAL EMISSIONS*



HYDROCARBONS

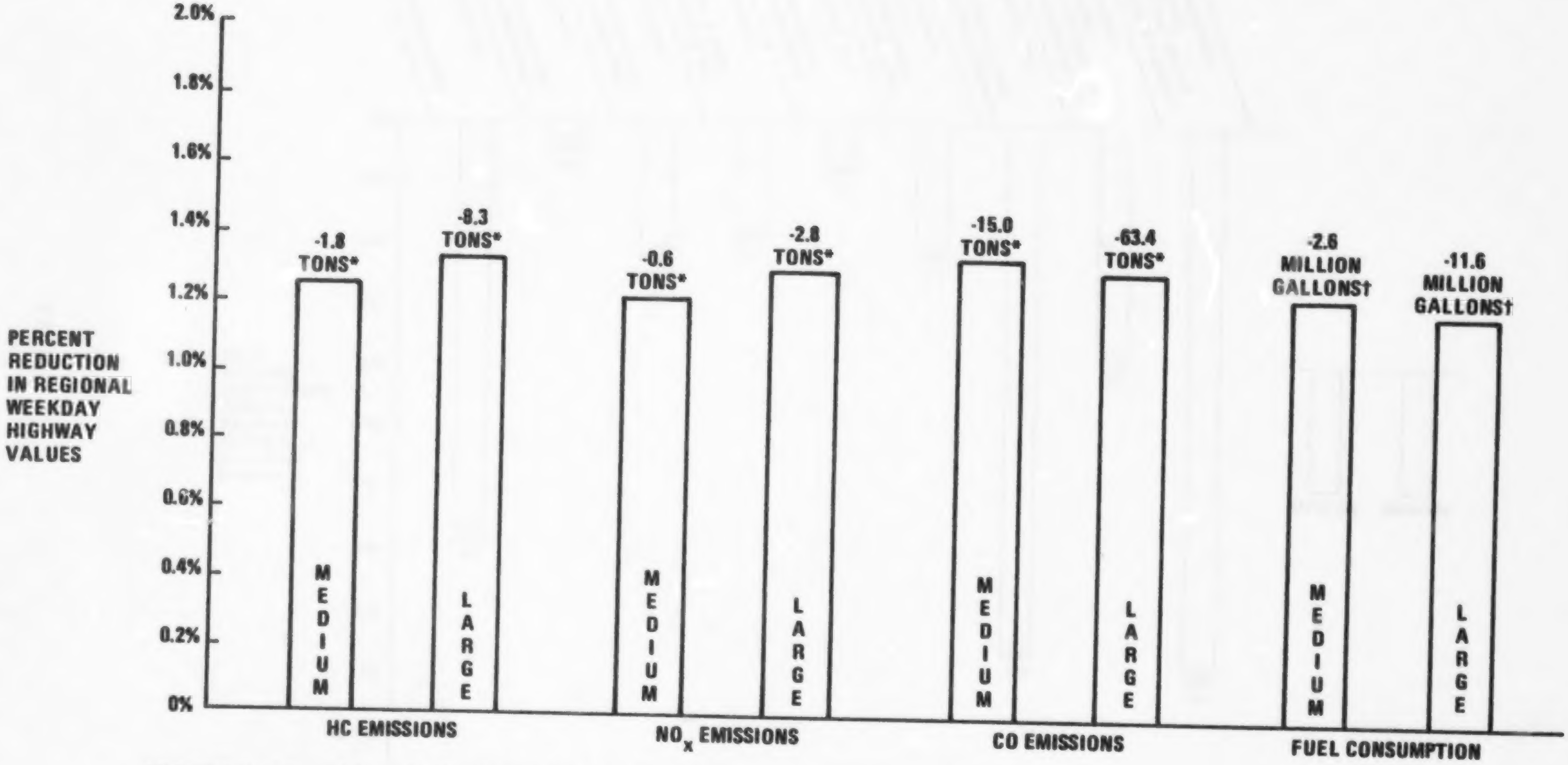
NITROGEN OXIDES

CARBON MONOXIDE

* Assumes uninterrupted traffic flow conditions.

EXHIBIT 20

COMPARISON OF ESTIMATED REGIONAL IMPACTS OF A CARPOOL/VANPOOL PROGRAM IMPLEMENTED IN TWO PROTOTYPE REGIONS : MEDIUM SIZE (500,000 - 1,000,000 POPULATION RANGE) AND LARGE (1,000,000 + POPULATION RANGE)



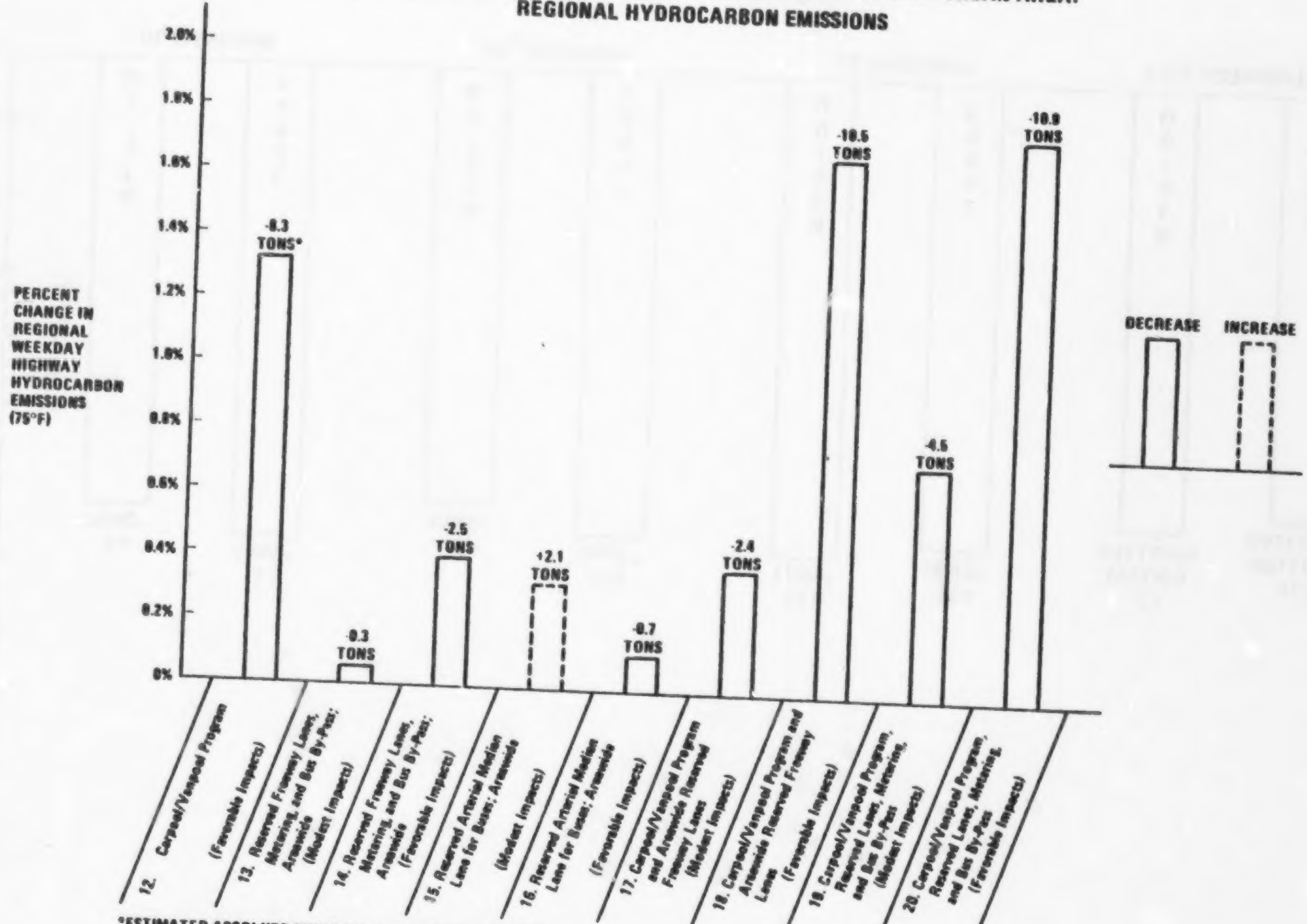
*Estimated absolute weekday regional emissions reductions in tons.
Estimates assume uninterrupted traffic flow conditions.

†Estimated absolute annual regional fuel consumption reduction in gallons.

[Above impact estimates are for Scenario 11 (Medium) and Scenario 12 (Large)].

EXHIBIT 21

ESTIMATED IMPACTS FOR NINE REGIONAL SCENARIOS IN A LARGE URBAN AREA: REGIONAL HYDROCARBON EMISSIONS

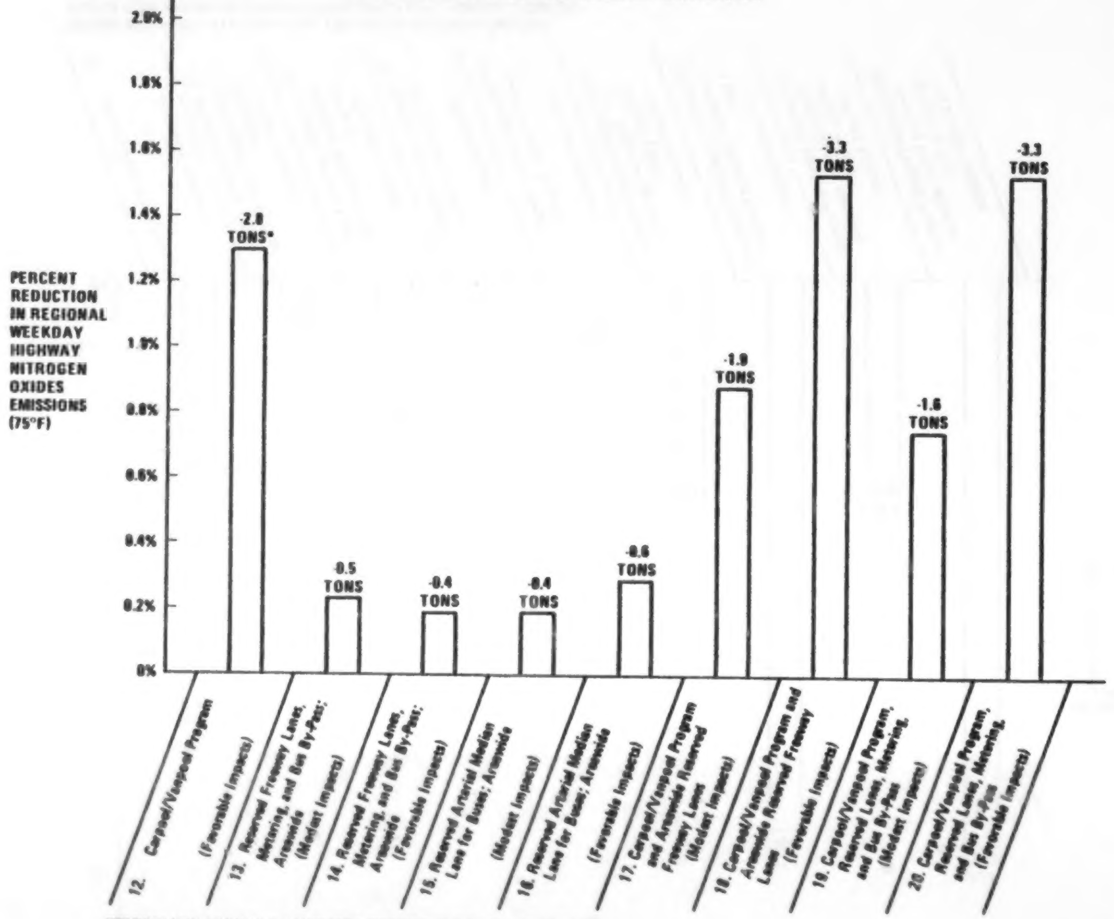


*ESTIMATED ABSOLUTE REGIONAL CHANGE IN HC EMISSIONS FOR PROTOTYPE URBAN REGION OF APPROXIMATELY 2,500,000 - 3,000,000 SMSA POPULATION AND AN AVERAGE BASE WEEKDAY HC HIGHWAY EMISSIONS OF 628 TONS (AT 75°F).

Estimates assume uninterrupted traffic flow conditions.

EXHIBIT 22

ESTIMATED IMPACTS FOR NINE REGIONAL SCENARIOS IN A LARGE URBAN AREA: REGIONAL NITROGEN OXIDES EMISSIONS



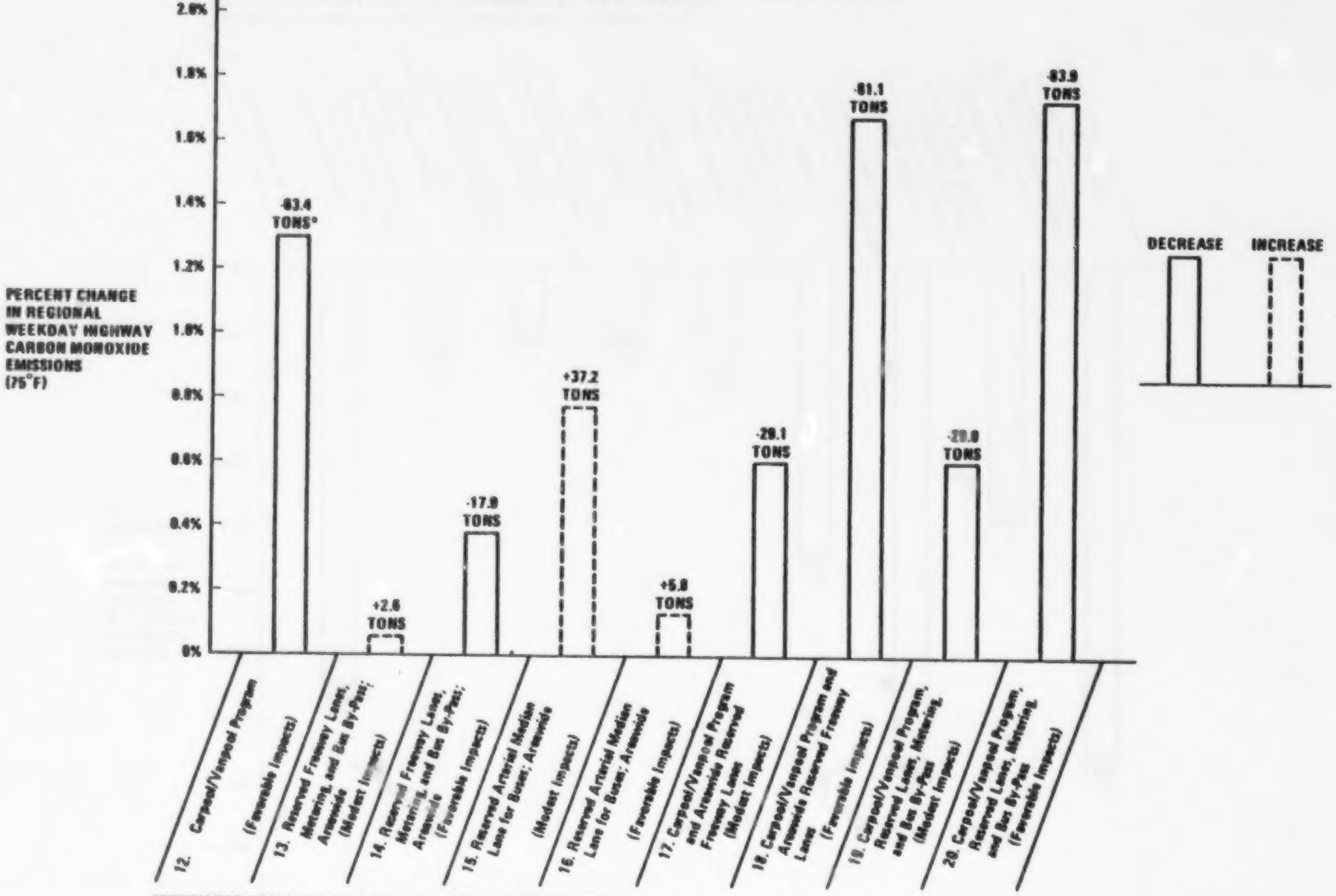
*ESTIMATED ABSOLUTE REGIONAL CHANGE IN NO_x EMISSIONS FOR PROTOTYPE URBAN REGION OF APPROXIMATELY 2,500,000 - 3,000,000 SMSA POPULATION AND AN AVERAGE BASE WEEKDAY NO_x HIGHWAY EMISSIONS OF 215 (AT 75°F).

Estimates assume uninterrupted traffic flow conditions.

EXHIBIT 23

ESTIMATED IMPACTS FOR NINE REGIONAL SCENARIOS IN A LARGE URBAN AREA:

REGIONAL CARBON MONOXIDE EMISSIONS



*ESTIMATED ABSOLUTE REGIONAL CHANGE IN CO EMISSIONS FOR PROTOTYPE URBAN REGION OF APPROXIMATELY 2,500,000 - 3,000,000 SMSA POPULATION AND AN AVERAGE BASE WEEKDAY CO HIGHWAY EMISSIONS OF 4,850 TONS (AT 75°F).

Estimates assume uninterrupted traffic flow conditions.

congestion on remaining non-reserved lanes)[1] more than counteracts the effects of the overall reduction in total VMT associated with these strategies. This is particularly true for the reserved lane scenarios in which only modest travel impacts are assumed. Under these circumstances, the congestion caused by removing a lane for exclusive use of buses or buses and carpools is reduced only slightly by the assumed modest shift from autos to preferentially treated high occupancy vehicles.

These prototype emission results again demonstrate the importance of initial travel and congestion conditions, highway facility design, and the relative magnitude of the induced modal shifts in determining the size and even direction of air quality impacts of corridor-related actions. These stratgies can be effective, but the selection, design, and implementation of such corridor or facility oriented actions must be carefully planned on a case-by-case basis in light of the above considerations to avoid ineffective or counterproductive air quality measures.

The dispersed nature of the VMT reductions associated with employer-based carpool/vanpool programs makes congestion impacts of regional significance unlikely. Thus, areawide carpool/vanpool programs can be expected to have emission impacts more consistently in line with overall regional VMT reductions. In designing and implementing such programs, the major concern should be to focus on those employers and employment concentrations which are not adequately served by public transportation.

Regional Fuel Consumption Impacts

Exhibit 24 presents the percentage changes in weekday highway fuel consumption estimated for each of the nine large city regional scenarios. All of the impacts are reductions, but they tend to be smaller reductions on a percentage basis than the corresponding VMT reductions (see Exhibit 28). This is again the result of congestion effects and the difference between the assumed average speed/facility type/vehicle type distribution of total regional VMT and the subset of regional VMT affected by the scenario strategy. However, the differences between percentage regional fuel consumption and VMT impacts are not as pronounced as for HC and CO emissions because of a somewhat lesser sensitivity of fuel consumption rates to speed. Exhibit 24 also indicates the absolute annual reduction in regional highway fuel consumption in millions of gallons for each of the large prototype regional scenarios.

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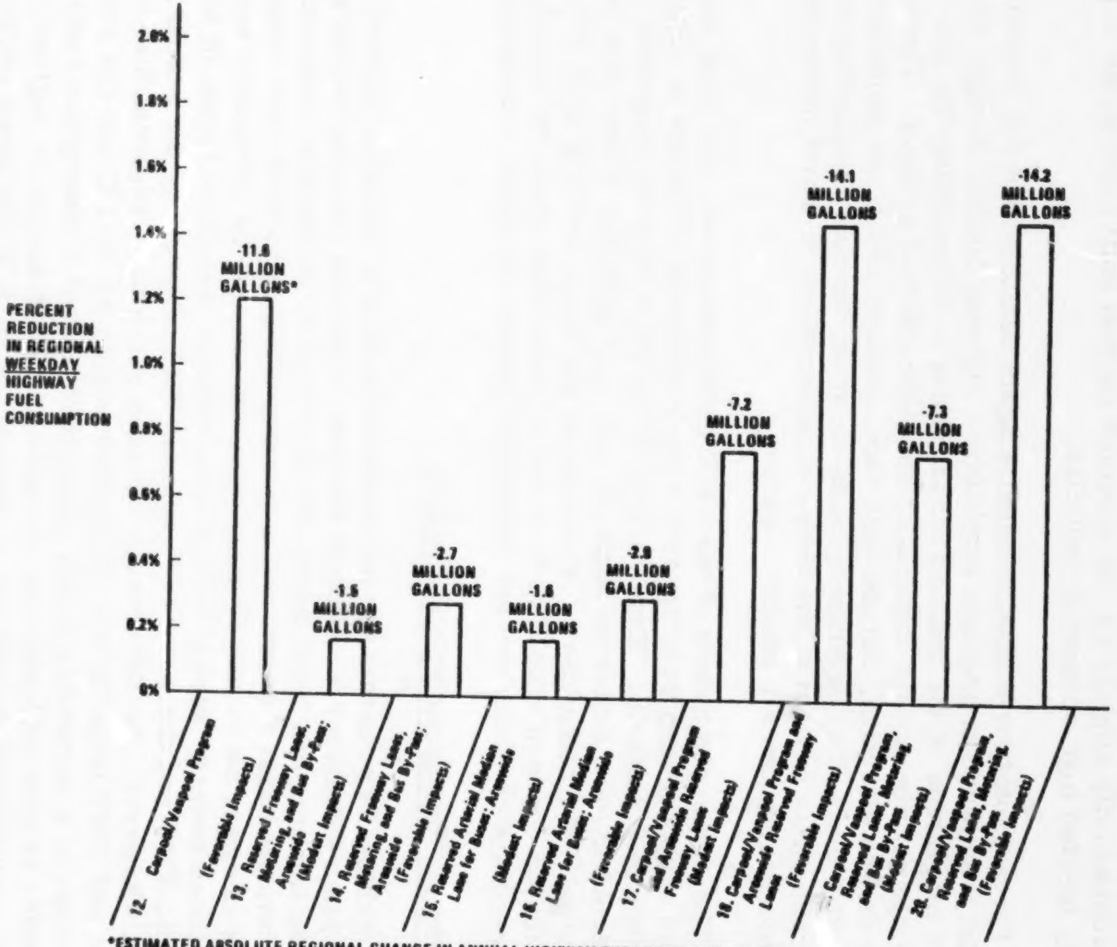
[1] See Table A.5 for a discussion of the travel impact methodology used to estimate VMT changes and average speed shifts associated with congestion for the regional scenarios.

EXHIBIT 24

ESTIMATED IMPACTS FOR NINE REGIONAL SCENARIOS IN A LARGE URBAN AREA: REGIONAL HIGHWAY FUEL CONSUMPTION



*ESTIMATED ABSOLUTE REGIONAL CHANGE IN ANNUAL HIGHWAY FUEL CONSUMPTION FOR PROTOTYPE URBAN REGION OF APPROXIMATELY 2,500,000 - 3,000,000 SMSA POPULATION AND A BASE ANNUAL HIGHWAY FUEL CONSUMPTION OF 1,300 MILLION GALLONS (FULL 365 DAYS, INCLUDING WEEKENDS AND HOLIDAYS).

Capital and Operating Costs

Exhibit 25 presents the estimated capital and annual operating costs for the regional scenarios. Appendix B presents the unit costs used in the development of the capital and annual costs.

The costs for the regional scenarios represent order of magnitude estimates. The development of detailed cost estimates was beyond the scope of the project. The capital and operating costs for the regional scenarios assume that some economies of scale would result from implementing reserved lanes, ramp metering, bus by-pass ramps, and expanded express bus service in multiple corridors within a large urban area. In this regard, the unit costs presented in Appendix B were reduced by 25 percent in estimating the capital and operating costs of the regional scenarios.

With the exception of scenarios 11 and 12, the largest individual cost item for all of the scenarios is for improvements to express bus service. Generally, the geographic coverage and the frequency of express bus service were assumed to increase significantly in order to complement the reserved HOV lanes and divert potentially large numbers of auto travelers. The annual cost of bus service shown in Exhibit 25 represents the incremental cost of providing bus service above that assumed in the base case (i.e., "before" case). As for the localized scenarios, the costs of implementing ramp metering and park-and-ride facilities also are significant.

Based on express bus operations in Minneapolis and Seattle, annual operating revenues may cover approximately 50 percent to 66 percent of annual operating and maintenance costs of express bus service presented in Exhibit 25. Sizeable annual operating subsidies may thus be needed to operate the assumed express bus services. Subsidy levels may be more significant if reduced fare programs are implemented.

Economic Impacts

The economic impacts of the regional scenarios are likely to be small. The nature and magnitude of the impacts are likely to be similar to those cited for the localized scenarios on page III. 22.

EXHIBIT 25

CAPITAL AND ANNUAL OPERATING AND MAINTENANCE COSTS FOR REGIONAL SCENARIOS

PROTOTYPE SCENARIO		Costs (in Thousands of 1976 Dollars)		
ID No.	TITLE	ITEM	CAPITAL	ANNUAL OPERATING AND MAINTENANCE
11	Carpool/Vanpool Program, Medium Size City; Favorable Impacts	Carpool Program*	—	$ 76
12	Carpool/Vanpool Program, Large City; Favorable Impacts	Carpool Program*	—	404
13	Reserved Bus/Pool Lanes, Ramp Metering and Bus By-Pass Lanes on All Appropriate Freeways; Modest Impacts	Ramp Metering	3,402	252
		Reserved Lane	300	660
		Bus By-Pass Ramps	1,380	—
		Express Bus Service	9,504	3,597
		Park and Ride Lots	0/4,860	744
			14,586/19,446	5,253
14	Reserved Bus/Pool Lanes, Ramp Metering, and Bus By-Pass Lanes on All Appropriate Freeways; Favorable Impacts	Ramp Metering	3,402	252
		Reserved Lane	300	660
		Bus By-Pass Ramps	1,380	—
		Express Bus Service	13,662	5,142
		Park and Ride Lots	0/4,860	744
			18,744/23,604	6,798
15	Reserved Median Lane for Express Buses on Appropriate Radial Arterials; Modest Impacts	Reserved Median Lanes	7,088	152
		Express Bus Service	11,781	5,402
		Park and Ride Lots	0/2,835	430
			18,869/21,704	5,984
16	Reserved Median Lane for Express Buses on Appropriate Radial Arterials; Favorable Impacts	Reserved Median Lanes	7,088	152
		Express Bus Service	11,781	5,402
		Park and Ride Lots	0/2,835	430
			18,869/21,704	5,984
17	Carpool/Vanpool Program and Freeway Reserved Lanes; Modest Impacts	Carpool Program	—	404
		Reserved Lanes	300	660
		Express Bus Service	9,504	3,600
		Park and Ride Lots	0/4,860	744
			9,804/14,664	5,408
18	Carpool/Vanpool Program and Freeway Reserved Lanes; Favorable Impacts	Carpool Program	—	404
		Reserved Lanes	300	660
		Express Bus Service	10,890	4,113
		Park and Ride Lots	0/4,860	744
			11,190/16,050	5,921
19	Carpool/Vanpool Program, Reserved Lanes, Ramp Metering, and Bus By-Pass Lanes; Modest Impacts	Carpool Program	—	404
		Ramp Metering	3,402	252
		Reserved Lane	300	660
		Bus By-Pass Ramps	1,380	—
		Express Bus Service	9,504	3,597
		Park and Ride Lots	0/4,860	744
			14,586/19,446	5,957
20	Carpool/Vanpool Program Reserved Lanes, Ramp Metering, and Bus By-Pass Lanes; Favorable Impacts	Carpool Program	—	404
		Ramp Metering	3,402	252
		Reserved Lane	300	660
		Bus By-Pass Ramps	1,380	—
		Express Bus Service	13,662	5,142
		Park and Ride Lots	0/4,860	744
			18,744/23,604	7,202

IV. SUMMARY AND ASSESSMENT OF SCENARIOS

This section summarizes and assesses the major impacts and the cost-effectiveness of the localized and regional scenarios analyzed in Section III. In addition, guidelines are presented for estimating the air quality and emission impacts of the transportation actions examined in this project. Important factors which may affect the transferability of the project's findings to specific locations are also discussed.

LOCALIZED SCENARIOS

Exhibit 26 summarizes the following impacts of the localized scenarios:

- impacts on peak hour vehicle volumes on affected highway facilipies;
- impacts on peak hour CO concentrations for both typical, good and typical, poor dispersion conditions; and
- the capital and annual operating and maintenance costs of the scenarios.

The freeway-based scenarios (i.e., scenarios 1-8) are likely to achieve reductions in overall peak hour corridor traffic volumes ranging between 1.5 percent and 7 percent. As illustrated below, the estimated reductions in peak direction peak hour traffic volumes on the freeways in these scenarios can be substantial if anticipated shifts to carpooling and transit are achieved.

Scenario	Percent Reduction in Peak Direction Peak Hour Freeway Vehicle Volumes[1]
1	3.2
2	13.7
3	6.7
4	N.A.[2]
5	14.6
6	3.8
7	8.4
8	8.4

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[1] These values are taken from the travel impact summary, Exhibit 10, appearing in Section III.

[2] Because of the breakdown in freeway flow projected in scenario 4, it is not meaningful to report a change in peak hour volume.

EXHIBIT 26

SUMMARY OF ESTIMATED IMPACTS FOR THE LOCALIZED PROTOTYPE SCENARIOS

PROTOTYPE SCENARIO		IMPACT ON A.M. PEAK HOUR CORRIDOR VEHICLE VOLUME*		IMPACT ON A.M. PEAK HOUR CO CONCENTRATIONS IN $\mu g/m^3$ AT REFERENCE RECEPTOR, FROM AFFECTED FACILITY EMISSIONS**				PROGRAM COSTS IN 1976 DOLLARS (x1,000)	
				TYPICAL, GOOD DISPERSION1		TYPICAL, POOR DISPERSION1			
ID No.	BRIEF TITLE	BASE PEAK HOUR VOLUME	PERCENT CHANGE	BASE VALUE	CHANGE	BASE VALUE	CHANGE	CAPITAL (ONE-TIME, IMPLEMENTATION)$^{(b)}$	OPERATING$^{(a)}$ (PER YEAR)
1	Expanded Express Bus Service in Mixed Freeway Traffic; Favorable Impacts	10,667	−1.47%	5,756	− 130	8,210	− 203	3,160/4,780$^{(b)}$	1,447
2	Freeway Lane Reserved for Buses and Carpools; Favorable Impacts	10,667	−6.30%	5,756	− 564	8,210	− 762	3,720/5,360	1,830
3	Ramp Metering and Bus By-Pass Lanes; Favorable Impacts	10,667	−3.06%	5,756	− 388	8,210	− 537	6,224/8,044	1,703
4	Reserved Bus/Pool Lane, Ramp Metering, and Bus By-Pass Lanes; Modest Impacts	10,667	−3.97%1*	5,756	N.A.@	8,210	N.A.@	4,862/6,482	1,751
5	Reserved Bus/Pool Lane, Ramp Metering, and Bus By-Pass Lanes; Favorable Impacts	10,667	−6.08%	5,756	− 603	8,210	− 832	6,248/7,868	2,260
6	Contraflow Freeway Lane Reserved for Buses; Favorable Impacts	14,750	−1.60%	4,708	+226	6,760	+277	962	641
7	Contraflow Bus Lane, Expanded Express Bus Service, and Park-and-Ride Lots; Favorable Impacts	14,750	−3.72%	4,708	+100	6,760	+104	3,668/5,288	1,818
8	Contraflow Bus Lane, Expanded Express Bus Service, and Lots; Assuming 70%/30% Directional Split; Favorable Impacts	13,500	−4.07%	4,066	− 115	5,740	− 101	3,668/5,288	1,810
9	Reserved Arterial Median Lane for Express Buses; Favorable Impacts	3,750	−15.47%	4,964	− 779	6,406	− 998	3,504/4,134	1,130
10	Contraflow Curb Lane for Local Buses on Pair of One-Way Arterials; Favorable Impacts. (Inbound Arterial/Outbound Arterial)	5,000	−4.40%	3,982 3,340	−532 +365	4,882 4,783	−685 +474	468	123

*On all highway facilities explicitly included in the analysis of the prototype corridor (see diagrams in Exhibit 8); in both directions. Volume is for freeway and/or arterial segments approximately 1 mile out from the CBD (adjacent to the CBD in the case of Scenario 10).

**CO concentration 50 feet from downwind edge of primary corridor facility, based on vehicular emissions from affected facilities only; uninterrupted traffic flow conditions are also assumed. Maximum 8 hour average CO concentrations may be approximated using the procedure in Exhibit 14.

1 See Exhibit 11 for a tabular description of these meteorological conditions.

1* This value includes the vehicles originally using the corridor freeway, but estimated as being unable to pass through during peak hour because of flow breakdown caused by congestion.

@CO Concentration impacts for Scenario 4 could not be reliably estimated. See Exhibit 10 and text for further explanation.

(a) Represents incremental operating costs

(b) The two capital cost entries represent the range in costs depending upon whether existing parking facilities (e.g., shopping center) or newly constructed facilities are required for park-and-ride lots.

The arterial scenarios analyzed (scenarios 9 and 10) also can promote percentage reductions in peak hour vehicular volumes ranging between 4 percent and 15 percent. As is true for the freeway scenarios, the attainment of such reductions is highly dependent upon the specific setting in which such strategies may be implemented. However, the percentage reductions in vehicular volumes for arterials are based on smaller base volumes and are not fully comparable to the corridor volumes in the freeway scenarios.

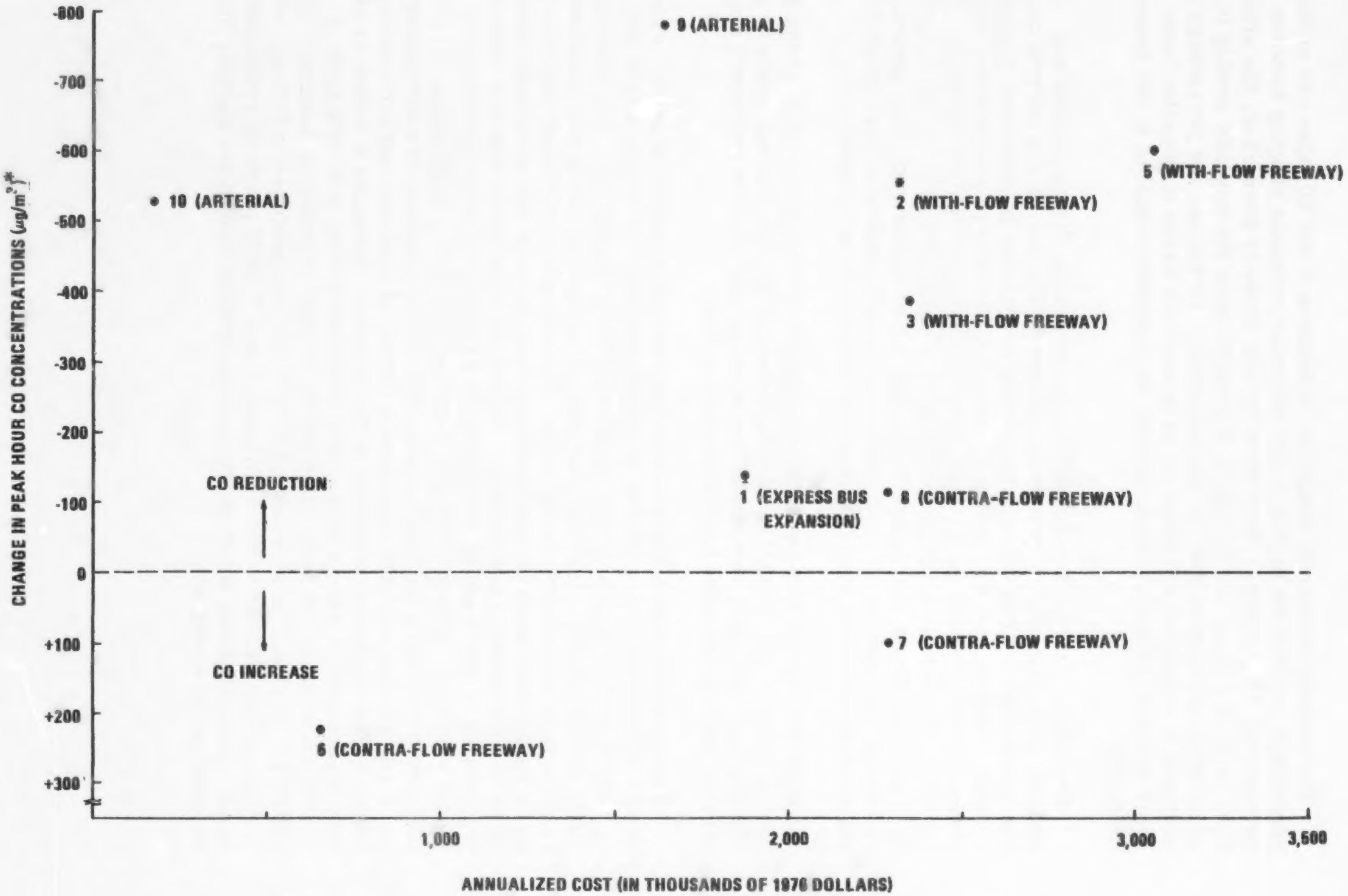
Generally the relative reductions in peak hour CO concentrations (under typical, good dispersion conditions) shown in Exhibit 26 are several percentage points higher than the corresponding reductions in peak hour corridor vehicle volumes, but are generally several percentage points lower than the corresponding reductions in peak direction freeway vehicle volumes. In scenarios 4, 6, and 7, CO concentrations are estimated to increase relative to the base conditions. Although the scenarios are illustrative in nature, the estimated increase in CO concentrations clearly indicates that careful analysis of alternative tactics on a case-by-case basis is necessary.

Both the capital and annual operating and maintenance costs of the localized scenarios are sizeable. As discussed in Section III, the costs of purchasing and operating new buses for express bus service represent a substantial part of the total cost of the scenarios.

The potential cost-effectiveness (expressed in terms of ug/m^3 reduction of CO concentration per $1,000 of annualized cost) of the localized scenarios in reducing CO concentrations is illustrated in Exhibit 27. The annualized costs in this exhibit represent the sum of annual operating and maintenance costs and an annualized capital cost. Transit and non-transit capital costs were annualized using an eight percent interest rate and economic lives of 12 and 20 years, respectively. Exhibit 27 illustrates that the cost-effectiveness of the freeway strategies in reducing CO concentrations is highly variable. Scenarios 6 and 7 which involve the application of contraflow reserved lanes for buses along with complementary transportation actions are clearly not cost-effective in terms of their air quality impacts based on the scenarios assumed in the project. Scenario 8 (which is identical to scenario 7 except that a 70%/30% rather than 60%/40% split of traffic volumes in the peak/off-peak directions of travel is assumed) is estimated to result in a reduction rather than an increase in CO concentrations. This suggests that scenarios 6 and 7 could promote reductions in CO concentrations under more suitable traffic conditions such as those assumed in scenario 8.

EXHIBIT 27

COMPARISON OF LOCALIZED SCENARIOS ON COST AND CO CONCENTRATION IMPACTS



*CO Concentrations are for Typical, Good Dispersion Meteorological Conditions, 50 feet downwind from edge of primary corridor facility

Exhibit 27 shows that, using scenario 1 as a "minimum action plan" base, scenario 2 produces a larger incremental reduction in CO concentrations than does scenario 3 for essentially the same incremental cost. The cost-effectiveness plot also shows that compared to scenario 2, scenario 5 is significantly more costly but yields only a marginal reduction in CO concentrations.

The cost-effectiveness analysis is primarily intended to illustrate the potential air quality improvements achieved per dollar of investment. Such a consideration is clearly important because of limited government financial resources available to improve air quality. However, it is important to recognize other potentially desirable impacts of these strategies in an evaluation process. Strategies incorporating transit improvements can maintain or enhance mobility when disincentives are applied to discourage travel by low-occupancy vehicles. Many of the strategies can yield significant travel time savings to travelers receiving priority treatment and can promote sizeable reductions in peak period vehicular traffic.

The rankings of strategies illustrated by Exhibits 26 and 27 reflect the transportation measures and characteristics assumed for each scenario in this analysis. This ranking, as well as the impacts for a given strategy, could be considerably different within a given urban area because of "local conditions." Major factors likely to influence the relative ordering between strategies and within a single class of strategies include:

- the characteristics (e.g., miles of reserved HOV lane, access/egress operations, type of transit service, enforcement, size and location of park and ride lots) of the transportation measures incorporated in the scenarios;

- the estimated level of transit ridership and ride-sharing increases which can vary substantially for similar projects as noted in Section II;

- the capital and operating costs of the strategies which are highly dependent on the physical and operating characteristics of an urban area's transportation system and local labor costs; and

- the prevailing meteorological conditions, traffic enforcement procedures, and levels of service (e.g., operating speeds and v/c ratios) on highways which are candidates for the types of scenarios analyzed.

In addition to the potentially large variation in impacts between different packages of transportation measures, considerably different magnitudes of impacts may result from implementing the same package of actions under different circumstances in urban areas. This possibility is suggested by the literature review in Section II and may change the relative ranking of scenarios analyzed in this report.

REGIONAL SCENARIOS

The VMT, emission, fuel consumption, and cost impacts of the ten regional TSM programs are summarized in Exhibit 28. Reductions in total regional VMT in the range of 1.0 to 1.9 percent are attributable to scenarios 11, 12, and 17 through 20 which involve carpool and vanpool programs focusing on large employers. These reductions correspond to reductions of 3 to 6.5 percent in weekday work trip VMT. This represents a substantial shift of low occupancy auto trips to transit, carpools, and vanpools during peak travel periods, which will reduce congestion and conserve energy as shown in Exhibit 28. These same scenarios also are estimated to yield the largest reductions in regional HC, NO_x, and CO emissions.

Scenarios 13 through 17, which involve the implementation of reserved lanes on multiple radial freeways or arterials in a region, generally resulted in total regional and work trip VMT reductions of less than 0.5 percent and 1.5 percent, respectively. The small reductions in VMT are in large part related to the limited size of the peak period radially-oriented CBD travel market in most large urban areas. For example, home to work trips and VMT comprise approximately 20 percent and 30 percent of total weekday regional person trips and VMT, respectively. Travel survey data suggests that only 15 percent of home to work trips are oriented to the CBD of urban areas exceeding 1 million population. However, those urban areas with especially large percentages of CBD-oriented travel could experience higher reductions in VMT than those estimated in this study.

Despite their limitations in reducing regional air pollution emissions, the freeway reserved lane strategies show considerable potential for reducing peak period travel congestion along radial travel corridors when applied under appropriate travel conditions. These strategies can contribute to reductions in CO concentrations along heavily traveled freeways and can also contribute to reductions of vehicular travel within CBD's.

Exhibit 29 illustrates (using HC emissions) that scenarios 11 and 12, which involve major employer carpool and vanpool programs, are particularly cost-effective in reducing regional air pollution emissions. Scenarios 13 through 17 which incorporate express bus service and reserved freeway or arterial lanes in multiple corridors are less cost-effective than scenario 12 in reducing HC emissions. The combination of carpool and vanpool programs with express

EXHIBIT 28

SUMMARY OF ESTIMATED IMPACTS FOR THE REGIONAL PROTOTYPE SCENARIOS

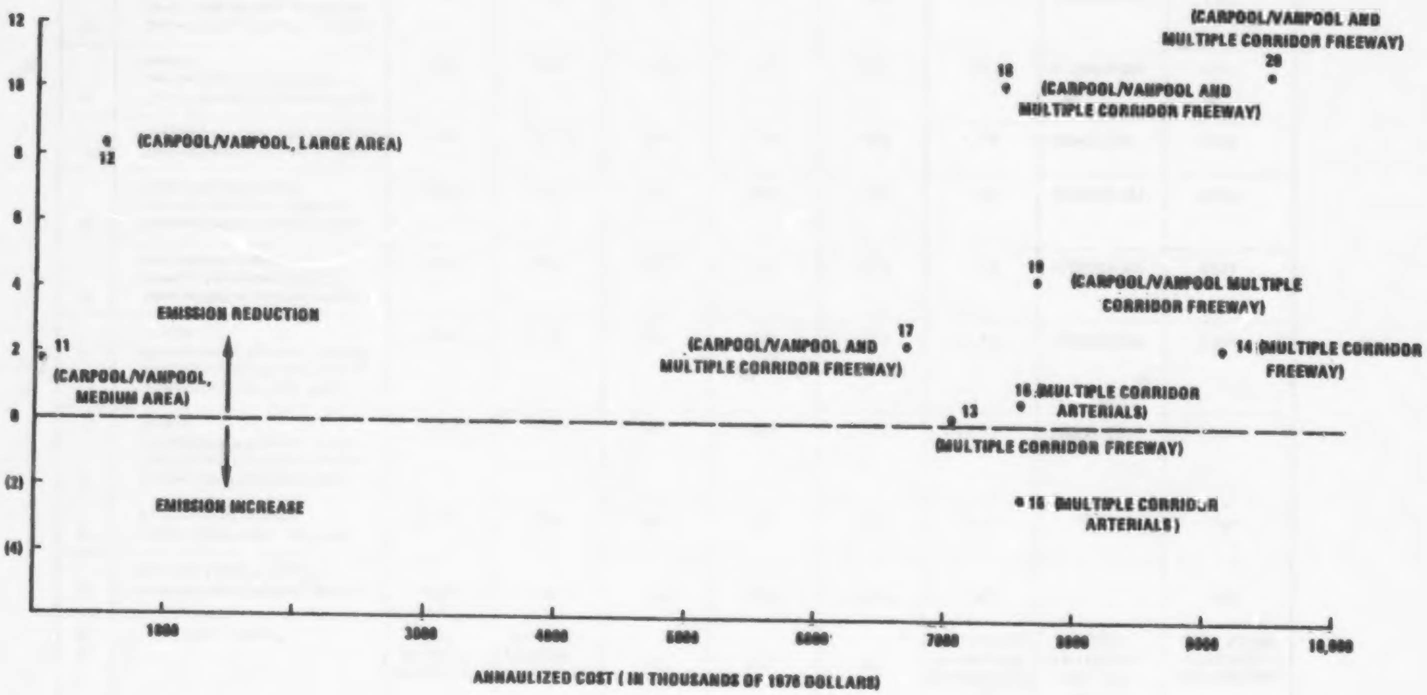
PROTOTYPE SCENARIO		CHANGE IN REGIONAL WEEKDAY VMT		CHANGE IN REGIONAL WEEKDAY HIGHWAY EMISSIONS IN TONS†			CHANGE IN ANNUAL HIGHWAY FUEL CONSUMPTION IN MILLIONS OF GALLONS	PROGRAM COSTS IN 1976 DOLLARS (x1,000)	
ID No.	BRIEF TITLE*	AS PERCENT OF TOTAL VMT	AS PERCENT OF WORK TRIP VMT	HC	NO_X	CO		CAPITAL (ONE-TIME, IMPLEMENTATION)	INCREMENTAL OPERATING (PER YEAR)
11	Carpool/Vanpool Program, Medium Size City; Favorable Impacts	–1.5%	–6.0%	– 1.0*	– 0.6*	–15.0*	– 2.0*	–	76
12	Carpool/Vanpool Program, Large City; Favorable Impacts	–1.5%	–5.0%	–8.3	– 2.8	–63.4	– 11.6	–	404
13	Reserved Bus/Pool Lanes, Ramp Metering, and Bus By-Pass Lanes on All Appropriate Freeways; Modest Impacts	–0.25%	–0.8%	–0.3	– 0.5	+ 2.6	– 1.5	14,580/19,440	5,263
14	Reserved Bus/Pool Lanes, Ramp Metering, and Bus By-Pass Lanes on All Appropriate Freeways; Favorable Impacts	–0.44%	–1.5%	–2.5	– 0.4	–17.0	– 2.7	10,744/23,604	6,790
15	Reserved Median Lane for Express Buses on Appropriate Radial Arterials; Modest Impacts	–0.23%	–0.8%	+2.1	– 0.4	+37.2	– 1.6	10,860/21,704	5,904
16	Reserved Median Lane for Express Buses on Appropriate Radial Arterials; Favorable Impacts	–0.38%	–1.3%	– 0.7	– 0.6	+ 5.8	– 2.9	10,860/21,704	5,904
17	Carpool/Vanpool Program and Freeway Reserved Lanes; Modest Impacts	–1.0%	–3.3%	– 2.4	– 1.9	– 20.1	– 7.2	9,804/14,664	5,400
18	Carpool/Vanpool Program and Freeway Reserved Lanes; Favorable Impacts	–1.9%	–6.3%	– 10.5	– 3.3	– 81.1	–14.1	11,190/16,050	5,921
19	Carpool/Vanpool Program, Reserved Lanes, Ramp Metering, and Bus By-Pass Lanes; Modest Impacts	–1.0%	–3.3%	– 4.5	– 1.8	–29.0	– 7.3	14,580/19,440	5,957
20	Carpool/Vanpool Program, Reserved Lanes, Ramp Metering, and Bus By-Pass Lanes; Favorable Impacts	–1.9%	–6.5%	– 10.9	– 3.3	– 83.9	–14.2	10,744/23,604	7,202

*All scenarios except #11 are for a "large" city (1,000,000 + SMSA population). Scenario 11 is set in a "medium size" city (500,000 - 1,000,000 SMSA population).

†Estimated at 75°F assuming uninterrupted traffic flow conditions.

EXHIBIT 29

COMPARISON OF REGIONAL SCENARIOS ON COST AND REGIONAL EMISSIONS IMPACTS



bus service/reserved lane strategies in scenarios 18 and 20 are estimated to result in larger reductions in HC emissions than Scenario 12 but for a significantly larger annualized cost. Transit capital and operating costs comprise a significant percentage of the total cost of scenarios 12 through 20.

As discussed for the localized scenarios on page IV.5, the cost-effectiveness analysis is primarily intended to illustrate the potential air quality improvements achieved per dollar of investment. However, a thorough evaluation should account for the transportation, energy conservation, and other potentially beneficial impacts of regional-type scenarios discussed in this section.

The magnitudes of the impacts for each class of regional scenario, and consequently the ranking between scenarios for a given urban area, could vary from those determined in this report. Important factors which may have a major impact in the relative ranking of the scenarios include: the specific transportation measures packaged in the scenarios, the estimated types and levels of travel impact, and the costs of implementing and operating the proposed scenarios.

GUIDELINES FOR AIR QUALITY ANALYSES

Interpretation of Findings

The report is intended to provide information to assist urban areas covered by EPA's Transportation Planning Guidelines:

- assessing the applicability and potential of the four classes of transportation programs described above for improving localized and regional air quality;

- estimating and evaluating the cost-effectiveness of such programs and their related travel, energy consumption, cost, and economic impact; and

- identifying key factors (e.g., meteorological conditions, vehicle type distributions and vehicle operating speeds) likely to affect air quality and air pollution emissions.

The above issues are addressed at a sketch planning scale of analysis.

The report illustrates the magnitude and types of air quality, emission, travel, fuel consumption, and cost impacts that could result from the implementation of selected transportation actions in settings similar to those described for the 10 localized and 10 regional scenarios. The reader should note that the impact estimates developed in the project are scenario-specific and great care must be taken in attempting to directly apply the results of this analysis to specific real-world circumstances.

For example, the increase in CO concentrations in several contra-flow reserved freeway lane scenarios reflects the travel and meteorological conditions assumed in those scenarios. The results do not indicate that contra-flow lanes, per se, have undesirable air quality effects, but rather illustrate the importance of carefully analyzing the potential air quality effects of implementing a contra-flow lane on freeways carrying heavy traffic volumes in the "off-peak" direction.

The impacts presented in this report also reflect assumed "modest" and "favorable" travel impacts based on the findings of the literature review in Section II. The travel impact estimates are considered to be reasonable, particularly in light of the wide range in travel impacts which have been observed in demonstration projects for given classes of transportation actions. However, substantially different travel impacts could occur in a specific application, depending upon the characteristics of the project under consideration.

The application of tactics such as pricing incentives/disincentives, auto restricted zones, area licensing, and parking, pricing and supply controls in conjunction with the reserved lane, carpool, vanpool, and related scenario tactics has not been examined in the projects. Such tactics offer considerable promise for achieving more significant reductions in VMT than those estimated in this project.

Factors Affecting Air Quality and Emissions

Important factors affecting transportation-related[1] air quality and emission impacts include:

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[1] It is important to point out that contributions to air pollution levels from non-transportation sources can be quite substantial and vary considerably in importance from area to area. In order to accurately interpret the significance of projected transportation-related air quality impacts, local planners must also consider the non-transportation sources of air pollution in their areas.

- meteorological conditions (e.g., temperature, wind direction and speed, stability class and mixing depth);
- transportation facility, vehicle capacity and geometric characteristics (e.g., elevated, at-grade);
- existing and projected vehicle operating speeds, directional splits of travel, vehicle mixes (e.g., age and vehicle type), and the modal splits on the affected transportation facilities and in the region;
- relative amount of VMT and/or vehicles operating in cold start, stabilized, and hot start operating conditions; and
- development characteristics (e.g., building heights) adjacent to transportation facilities.

The above list includes data not typically compiled and used for either short-range or long-range urban transportation planning. It is especially important to recognize that a thorough analysis of localized transportation strategies will require the use of corridor and link specific information in estimating CO concentrations. MPO's and other agencies participating in air quality planning will have to assess the need for revised analysis and data collection programs to support their air quality planning process.

The development of a program to monitor the effectiveness of transportation actions in improving air quality is required by the Planning Process Guidelines. Such a program would be useful to ensure that implemented short range and long-range transportation improvements are achieving desired improvements in air quality.

The effect of increasingly stringent vehicle emission standards coupled with the growth in compact car ownership will contribute to reducing total tons of HC, NO_x and CO emissions over time. These are important developments which states and MPO's must account for in estimating 1982 emissions and air quality for updates to the State Implementation Plans required by the Clean Air Act Amendments for 1977.

Although these trends have not been quantatively analyzed in this project, their effects can be estimated using EPA's mobile source emission factors which reflect legislative requirements for future vehicle emission rates, by vehicle type.

Selection of TSM Actions for Analysis

The analysis of the prototype localized and regional scenarios demonstrates the need to clearly define the geographic scale of the air quality problems facing an urban area. The selection of transportation measures for analysis should be consistent with the scale of the area's air quality problems. Many measures, such as reserved HOV lanes, are particularly applicable to alleviating localized air quality problems while other tactics, such as carpool and vanpool programs, are appropriate for addressing regional air quality problems.

For example, the results of the regional scenarios illustrate that the application of the HOV freeway or arterial lanes on multiple radial highways was substantially less effective in reducing regional air pollution emissions than the carpool/vanpool programs. However, these same strategies were considerably more effective in reducing CO concentrations adjacent to applicable freeways and arterials.

APPENDIX A

ANALYTICAL ASSUMPTIONS AND METHODOLOGY FOR NON-COST IMPACT ESTIMATES

A.1: Overview of Technical Approach for Air Quality Impacts Analysis

A.2: Base Travel Conditions for Localized (Corridor) Prototypes

A.3: Base Travel Conditions for the Regional Prototypes

A.4: Estimating Travel Shifts for Localized Prototype Scenarios

A.5: Estimating Travel Shifts for Regional Prototype Scenarios

A.6: Estimating Highway Emissions

A.7: Estimating Localized Concentration Impacts

A.8: Estimating Regional Fuel Consumption Impacts

A.9: Illustrative Calculation of Travel Shifts

TABLE A.1

OVERVIEW OF TECHNICAL APPROACH FOR AIR QUALITY IMPACTS ANALYSIS

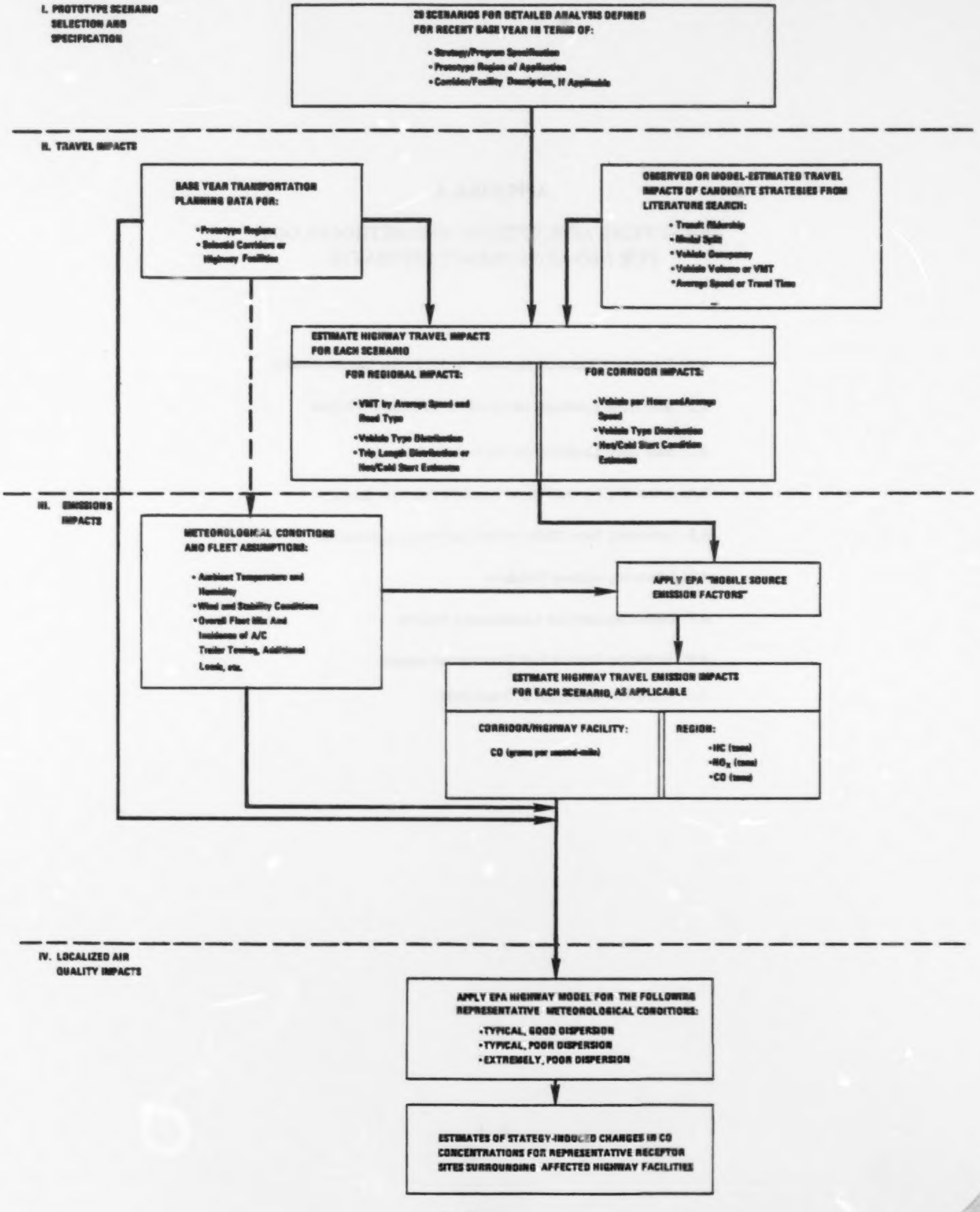
I. PROTOTYPE SCENARIO SELECTION AND SPECIFICATION
20 SCENARIOS FOR DETAILED ANALYSIS DEFINED FOR RECENT BASE YEAR IN TERMS OF:
• Strategy/Program Specification
• Prototype Region of Application
• Corridor/Facility Description, If Applicable
II. TRAVEL IMPACTS
BASE YEAR TRANSPORTATION PLANNING DATA FOR:
• Prototype Regions
• Selected Corridors or Highway Facilities
OBSERVED OR MODEL-ESTIMATED TRAVEL IMPACTS OF CANDIDATE STRATEGIES FROM LITERATURE SEARCH:
• Transit Ridership
• Modal Split
• Vehicle Occupancy
• Vehicle Volume or VMT
• Average Speed or Travel Time
ESTIMATE HIGHWAY TRAVEL IMPACTS FOR EACH SCENARIO
FOR REGIONAL IMPACTS:
• VMT by Average Speed and Road Type
• Vehicle Type Distribution
• Trip Length Distribution or Hot/Cold Start Estimates
FOR CORRIDOR IMPACTS:
• Vehicle per Hour and Average Speed
• Vehicle Type Distribution
• Hot/Cold Start Condition Estimates
III. EMISSIONS IMPACTS
METEOROLOGICAL CONDITIONS AND FLEET ASSUMPTIONS:
• Ambient Temperature and Humidity
• Wind and Stability Conditions
• Overall Fleet Mix And Incidence of A/C Trailer Towing, Additional Loads, etc.
APPLY EPA "MOBILE SOURCE EMISSION FACTORS"
ESTIMATE HIGHWAY TRAVEL EMISSION IMPACTS FOR EACH SCENARIO, AS APPLICABLE
CORRIDOR/HIGHWAY FACILITY:
CO (grams per second-mile)
REGION:
• HC (tons)
• NO$_x$ (tons)
• CO (tons)
IV. LOCALIZED AIR QUALITY IMPACTS
APPLY EPA HIGHWAY MODEL FOR THE FOLLOWING REPRESENTATIVE METEOROLOGICAL CONDITIONS:
• TYPICAL, GOOD DISPERSION
• TYPICAL, POOR DISPERSION
• EXTREMELY, POOR DISPERSION
ESTIMATES OF STATEGY-INDUCED CHANGES IN CO CONCENTRATIONS FOR REPRESENTATIVE RECEPTOR SITES SURROUNDING AFFECTED HIGHWAY FACILITIES

TABLE A.2:

BASE TRAVEL CONDITIONS FOR LOCALIZED (CORRIDOR) PROTOTYPES

ANALYTICAL ASSUMPTIONS AND PROCEDURES	BASIS OR SOURCE	COMMENTS
I. GENERAL		
A. VEHICLE CAPACITIES Freeway Lane: 1,750 vehicles per hour Arterial Lane, No Parking: 800 vehicles per hour	Tables 33 and 34, Characteristics of Urban Transportation Systems (CUTS Manual)	At level of service "E"
B. AVERAGE SPEEDS Based on computed volume to capacity ratios. Assume all segments in CO impact area can be categorized as "Fringe" location.	Tables 33 and 34, CUTS Manual and 1965 Highway Capacity Manual	Speeds for local buses judgmentally set based on typical ranges cited in ITE Transportation and Traffic Engineering Handbook, p. 218.
C. BASE VEHICLE VOLUMES Except when otherwise specified, for a.m. peak hour: • Inbound freeways at capacity (V/C = 1.00) • When primary corridor facility, inbound arterial near capacity (V/C = 0.94) • When competing with freeway, inbound arterial below capacity (V/C = 0.75) • Directional split of traffic on all facilities is 60% inbound and 40% outbound. (70%/30% on freeway for Scenario 8 only, by assumption.)	Prototype assumptions	Capacity conditions chosen to reflect realistic peak hour conditions on radial highway facilities. Over-capacity base conditions rejected as not appropriate for types of programs to be tested on these prototypes.
D. VEHICLE TYPE DISTRIBUTION Except for scenarios 9 and 10, a.m. peak hour vehicle type percentage distribution: Vehicle Type — Freeway — Arterial Single occupant auto — 71.0% — 70.1% Two occupant auto — 18.9% — 18.7% 3+ Carpool (ave. occ. = 3.6) — 4.7% — 4.7% Local bus (ave. occ. = 55) — 0% — 1.8% Express bus (ave. occ. = 45) — 0.4% — 0% Truck — 5.0% — 5.0%	NCHRP Report 143, p. 88 Peat, Marwick, Mitchell & Co., Carpooling Impact Study, Technical Memo II, February, 1976 Final Report, I-35W Urban Corridor Demonstration Project, p. 19-A Prototype assumptions	For relative distribution of 1 occupant, 2 occupant, and 3+ occupant autos. For relative distribution of carpools by number of occupants. For the relative percent bus. For the relative percent truck, distribution of corridor base as between freeway (express) and arterial (local), and average bus occupancies.
E. AVERAGE TRIP TRAVEL TIME Computed based on 10 miles travel on primary corridor facility, as follows: .5 mile in CBD, 2.5 miles in fringe area, 5.5 miles in outlying business district, and 1.5 miles in residential area.	Prototype assumptions. Four areas are Highway Capacity Manual categories used to estimate speed.	V/C ratio for CO impact area segment and area type distinctions used to estimate speeds over 4 portions of 10 mile trip. Travel time estimates used only to support assumptions on magnitude of modal shifts which a program can be expected to cause.

(Continued)

TABLE A.2:

(CONTINUATION 1)

ANALYTICAL ASSUMPTIONS AND PROCEDURES	BASIS OR SOURCE	COMMENTS
II. FOR SCENARIO 9 (5 LANE ARTERIAL) **A. VEHICLE TYPE DISTRIBUTION** For a.m. peak hour: Vehicle Type Single occupant auto 70.8% Two occupant auto 18.9% 3+ Carpool (ave. occ. = 3.0) 4.7% Local bus (ave. occ. = 55) 0.7% Express bus (ave. occ. = 45) 0% Truck 5.0%	Same as for I.D, except: Assume no express bus service in (arterial) corridor before program implemented. Assume relatively low initial local bus volume (15 in peak hour, inbound).	Changes are warranted: • because this prototype contains no freeway facility in corridor • by scenario assumption of relatively high modal shifts ("favorable" impacts), which would be impossible with high initial transit ridership
III. FOR SCENARIO 10 (PAIR OF ONE-WAY ARTERIALS) **A. VEHICLE TYPE DISTRIBUTION** For a.m. peak hour: Vehicle Type Single occupant auto 70.1% Two occupant auto 18.7% 3+ Carpool (ave. occ. = 3.0) 4.7% Local bus (ave. occ. = 50) 1.3% Express bus (ave. occ. = 45) 0.2% Truck 5.0%	Same as for I.D, except: Assume limited number of express buses (5 in peak hour, inbound). Assume 40 inbound peak hour local buses (the lower end of the 40-60 bus volume cited in NCHRP Report 155 as a warrant for the proposed type of curb lane strategy).	On a major 4 lane, one-way arterial, a small number of "express" buses were considered reasonable. Average local bus occupancy was set at the slightly lower value of 50 to maintain initial ridership at not too high a level (consistent with the assumption of moderately favorable impacts) while satisfying the minimum bus volume warrant of 40.

TABLE A.3:

BASE TRAVEL CONDITIONS FOR THE REGIONAL PROTOTYPES

<table>
<tr><th>ANALYTICAL ASSUMPTIONS AND PROCEDURES</th><th>BASIS OR SOURCE</th><th>COMMENTS</th></tr>
<tr><td>

I. GENERAL

A. ASSUMED SPEED BY LEVEL OF SERVICE CLASS

<table>
<tr><th>Level of Service / Road Type</th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr>
<tr><td>FREEWAY</td><td>55</td><td>55</td><td>50</td><td>40</td><td>33</td><td>20</td></tr>
<tr><td>ARTERIAL</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>All but local bus</td><td>35</td><td>27</td><td>22</td><td>17</td><td>15</td><td>8</td></tr>
<tr><td>Local bus</td><td>25</td><td>20</td><td>14</td><td>10</td><td>8</td><td>5</td></tr>
<tr><td>LOCAL/COLLECTOR</td><td>15</td><td>15</td><td>15</td><td>10</td><td>5</td><td>5</td></tr>
</table>

</td><td>Average speeds based on interpolations of speed values for the stated levels of service in the Highway Capacity Manual, supplemented by judgmental assumptions where necessary.</td><td>Average speeds in excess of 55 mph were not permitted.
Assumed valid for travel impacts (i.e., VMT changes) as well as base volumes.</td></tr>
<tr><td>

B. ASSUME V/C RATIOS BY LEVEL OF SERVICE

<table>
<tr><th>Level of Service / Road Type</th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr>
<tr><td>FREEWAY
Assumed V/C
Average
Class Range</td><td>.30
<.40</td><td>.50
.40-.58</td><td>.65
.58-.73</td><td>.78
.73-.82</td><td>.95
.82-1.00</td><td>1.05
1.00-1.10</td></tr>
<tr><td>ARTERIALS
Assumed V/C
Average
Class Range</td><td>.40
<.6</td><td>.65
.6-.7</td><td>.75
.7-.8</td><td>.85
.8-.9</td><td>.95
.9-1.0</td><td>1.05
1.0-1.1</td></tr>
</table>

</td><td>Highway Capacity Manual. A "peak hour factor" (as defined in HCM) of .91 was assumed).</td><td>Assumed valid for travel impacts as well as base values.</td></tr>
<tr><td>

II. MEDIUM SIZED REGION

A. BASE REGIONAL WEEKDAY HIGHWAY VMT
(WEEKDAY VMT IN 1000's)*

<table>
<tr><th colspan="2">ROAD AND VEHICLE TYPE</th><th>VMT IN 1,000's</th><th>PERCENT OF TOTAL</th></tr>
<tr><td>FREEWAY</td><td>AUTO</td><td>1,992.3</td><td>20.23%</td></tr>
<tr><td></td><td>EXPRESS BUS</td><td>4.7</td><td>0.05%</td></tr>
<tr><td></td><td>TRUCK</td><td>401.8</td><td>4.08%</td></tr>
<tr><td></td><td>SUBTOTAL</td><td>2,398.8</td><td>24.36%</td></tr>
<tr><td>ARTERIAL</td><td>AUTO</td><td>4,790.8</td><td>48.66%</td></tr>
<tr><td></td><td>LOCAL BUS</td><td>19.1</td><td>0.19%</td></tr>
<tr><td></td><td>TRUCK</td><td>967.5</td><td>9.83%</td></tr>
<tr><td></td><td>SUBTOTAL</td><td>5,777.4</td><td>58.68%</td></tr>
<tr><td colspan="2">Collector/Local (Auto Only)</td><td>1,669.8</td><td>16.96%</td></tr>
<tr><td colspan="2">GRAND TOTAL</td><td>9,846.0</td><td>100.00%</td></tr>
</table>

*These VMT values are further disaggregated by six level of service categories (A through F) as indicated to the right.

</td><td>Total VMT Value: Average total 1972 weekday VMT for 28 regions reporting in the 500,000-1,000,000 population group, National Transportation Report, Urban Data Supplement (NTR), Table D-1.
Facility Type Distribution: Using facility type distribution across all of above 28 regions from same data source.
Level of Service Distribution: Using sample highway assignment model VMT by LOS summary for Allegheny County (Pittsburgh). For local/collector roads, arterial distribution used, except LOS E and F are assumed excluded.
Vehicle Type Distribution: Same as I.D in Table A.2. For analytical simplicity only autos considered for collector/local roads.</td><td>Annual VMT was converted to weekday VMT with an annualization factor of 339.5
Medium-sized prototype region assigned values of average of 28 regions in 500,000-1,000,000 population group (average SMSA employment = 283,500)
Average occupancy of "Auto" when there is no breakdown into occupancy subgroups is 1.33.
Since summaries were available only for 24 hour average LOS, a more congested central county, year 2000 summary was used to simulate current peak hour conditions.
VMT matrix achieved by applying each of three distributions to total VMT using an independence assumption.</td></tr>
</table>

(Continued)

TABLE A.3

(CONTINUATION 1)

<table>
<tr><th>ANALYTICAL ASSUMPTIONS AND PROCEDURES</th><th>BASIS OR SOURCE</th><th>COMMENTS</th></tr>
<tr><td>
III. LARGE REGION
A. BASE REGIONAL WEEKDAY HIGHWAY VMT
(WEEKDAY VMT IN 1000's)*
<table>
<tr><th colspan="2">ROAD AND VEHICLE TYPE</th><th>VMT IN 1,000's</th><th>PERCENT OF TOTAL</th></tr>
<tr><td rowspan="4">FREEWAY</td><td>AUTO</td><td>10,219.5</td><td>23.26%</td></tr>
<tr><td>EXPRESS BUS</td><td>24.2</td><td>0.06%</td></tr>
<tr><td>TRUCK</td><td>2,060.9</td><td>4.69%</td></tr>
<tr><td>SUBTOTAL</td><td>12,304.6</td><td>28.00%</td></tr>
<tr><td rowspan="4">ARTERIAL</td><td>AUTO</td><td>18,213.1</td><td>41.45%</td></tr>
<tr><td>LOCAL BUS</td><td>72.6</td><td>0.17%</td></tr>
<tr><td>TRUCK</td><td>3,678.1</td><td>8.37%</td></tr>
<tr><td>SUBTOTAL</td><td>21,963.7</td><td>49.98%</td></tr>
<tr><td colspan="2">Collector/Local (Auto Only)</td><td>9,676.7</td><td>22.02%</td></tr>
<tr><td colspan="2">GRAND TOTAL</td><td>43,945.0</td><td>100.00%</td></tr>
</table>
*These VMT values are further disaggregated by six level of service categories (A through F), as indicated to the right.
</td>
<td>Total VMT Value and Facility Type Distribution obtained as in II.A of this table, but for 23 reporting regions in the 1,000,000 + population range.

Level of Service Distribution and Vehicle Type Distribution exactly as in II.A of this table.</td>
<td>Same comments as for II.A of this table, except that the large prototype region assigned values of average of 23 regions in 1,000,000 + population group (average SMSA employment = 1,152,700).</td></tr>
</table>

TABLE A.4:

ESTIMATING TRAVEL SHIFTS FOR LOCALIZED PROTOTYPE SCENARIOS

ANALYTICAL ASSUMPTIONS AND PROCEDURES	BASIS OR SOURCE	COMMENTS
I. GENERAL		
A. BUS SERVICE EXPANSION		
If the prototype strategy/program explicitly includes an expansion of express bus service, the base number of express buses during the a.m. peak hour are assumed to double or increase until a "comfortable" average occupancy of 40 is achieved at the final equilibrium ridership level, whichever is the larger increase in buses.	Definition of assumed prototype bus service expansion strategy.	
If the prototype strategy/program does not itself call for an initial expansion of service, then any increases in ridership are assumed to be absorbed partly by an increase in average express bus occupancy up to 50 and partly by an increase in buses to satisfy the final equilibrium ridership at the higher occupancy level.	Strategy definition.	
B. SOURCE OF FREEWAY BUS RIDERSHIP INCREASES		
Relevant freeway express bus service is assumed to consist of routes with some (but not extensive) local collector service in addition to the dominant freeway line-haul portion.		
If the strategy/program explicitly includes an expansion of bus service, 10% of any ridership increase is assumed to be previously unmade trips (induced travel).	Values from similar past experiences: • I-95 in Miami: 14% (*Service and Methods Demonstration Program Annual Report*, UMTA, 1977) • Blue Streak service in Seattle: 18% (*Blue Streak Bus Rapid Transit Demonstration Project – Final Report*)	Lower value of 10% assumed because: • this analysis is for a.m. peak hour and not both peak periods during which a higher percent of induced travel would be likely • cited results are from surveys which would yield some small percent of new riders even if conducted on an unchanged route
If the program does not explicitly include an expansion of bus service, none of any ridership increases is assumed to come from previously unmade trips.	Travel impact assumption	
Of the remaining ridership increase, the sources are assumed to be shifts from other modes as follows: Source of Increase — Percent of Person Trip Local (arterial) bus — 20% Arterial auto* — 16% Freeway auto*† — 64%	Values from similar past experiences for percent from bus: • I-95, Miami: <10% • I-35W, Minneapolis: 41% (*Final Report for the I-35W Urban Corridor Demonstration Project*) • Kalanianaole Highway, Honolulu: 18% ("Express Bus Use in Honolulu: a Case Study," *Transportation Research Record 606*)	For percent from arterial bus, a value at the lower end of the range (20%) was chosen since the higher value for I-35W (41%) was for a project in which new express bus service was provided that had extensive collector functions, not assumed in the prototype programs.
	For the percent from arterial and freeway auto, values from the I-35W experience were used.	The actual percentages were normalized to sum to the 80% remaining after the assumed 20% local bus share was removed.

(Continued)

TABLE A.4

(CONTINUATION 1)

ANALYTICAL ASSUMPTIONS AND PROCEDURES	BASIS OR SOURCE	COMMENTS
	(Continued)	
*Within the automobile categories, shifts from 1, 2, and 3+ occupant autos are allocated in proportion to the base number of persons in each category.	Primarily, a travel impact assumption	This assumption is basically consistent with limited available information from the Kalanianaole Highway, Blue Streak, and I-95 experiences on auto driver/passenger or 1 occupant/2+ occupant splits.
†For shifts from freeway auto to transit, none of the shift is assumed to come from 3+ occupant autos (carpools) when the strategy/program includes priority treatment for carpools also.	Assumption	
Decreases in local bus ridership are assumed to result in decreased average local bus occupancy rather than any decreases in a.m. peak buses.	Travel impact assumption.	Not unreasonable, given normal practice for small ridership declines.
C. SOURCE OF FREEWAY CARPOOL INCREASES		
None of any increase in freeway carpools during a.m. peak hour is assumed to be associated with previously unmade trips (induced travel).	Assumption	
The sources of any increase in freeway carpools are assumed to be shifts from other modes as follows:		
Source of Increase — Percent of Person Trips Arterial carpool — 10% Arterial auto (1, 2 occ.)* — 18% Freeway auto (1, 2 occ.)* — 72%	For percent from arterial carpool, travel impact assumption. The percents from arterial and freeway autos, respectively, are based on the same I-35W values used in I.B of this table, but normalized to sum to 90% instead of 80%.	This value (10%) is one-half of the arterial transit-to-freeway shift value (20%) used above. This is consistent with the fact that the arterial percentage share (out of the corridor total) for transit is twice the percentage share for carpools in the prototype travel conditions assumed.
*Within the automobile categories, shifts from 1, 2, and 3+ occupant autos are allocated in proportion to the base number of persons in each category.	Same assumption used for shifts to transit in I.B.	
D. SOURCE OF EXPRESS BUS RIDERSHIP INCREASES ON ARTERIAL WITH RESERVED MEDIAN LANE		
Of the original local bus ridership on arterial, assume 15% can make effective use of express bus service introduced and shift to express bus.	Assumption.	
Since there is an expansion of bus service for all strategy/programs associated with this prototype, assume 10% of ridership increase is previously unmade trips.	Same assumption used in I.B of this table for freeway prototypes.	
Of the remaining bus ridership increase, all of it comes from arterial autos, distributed across 1, 2, and 3+ occupant categories in proportion to the base number of persons associated with each.	Same assumption used in I.B of this table for freeway prototypes.	
The number of new buses introduced for the a.m. peak hour which is associated with the introduction of median lane express bus service is set at that which will yield a very comfortable average bus occupancy of 35.	Definition of prototype strategy/program.	Low occupancy value selected to reflect a fairly high level of service, designed to encourage ridership.

(Continued)

TABLE A.4

(CONTINUATION 2)

ANALYTICAL ASSUMPTIONS AND PROCEDURES			BASIS OR SOURCE	COMMENTS
E. SOURCE OF LOCAL BUS RIDERSHIP INCREASES ON RESERVED CONTRAFLOW ARTERIAL CURB LANES				
Any existing express bus ridership on facility remains stable.			Assumption.	The curb lane offers no benefits to either express buses or their current users.
Since there is no expansion of bus service associated with the relevant strategy/program, none of the local bus ridership increase is assumed to be previously unmade trips.			Same assumption used in I.B of this table for freeway prototypes.	
All local bus ridership increases come from arterial users, distributed across 1, 2, and 3+ occupant categories in proportion to the base number of persons associated with each.			Assumption.	Occupancy distribution same as that assumed in I.D. above.
F. CONGESTION DELAYS AND ROUTE DIVERSIONS				
On freeways, when the V/C ratio exceeds 1.1, breakdown of flow is presumed. Only 10% of the traffic in excess of capacity divert to parallel arterials. The remaining 90% over capacity is assumed to still use the freeway, but be unable to pass through during the peak hour.			Travel impact assumption.	Assumption consistent with frequency of extreme over-capacity congestion on some freeways (little diversion to arterials).
When the V/C ratio exceeds 1.00 on freeways, continuous flow can no longer be presumed. No single lower average speed can be reliably assigned. Thus, the average speed for V/C = 1.00 is reported, together with a rough estimate of stop-and-go delay in minutes.			Estimate of stop-and-go delay is based on a formula adapted from a queuing model delay formula. See P. 65 of: Guidelines for Travel Demand Analyses of Program Measures to Promote Carpools, Vanpools and Public Transportation (Prepared by Cambridge Systematics, Inc. for FEA, 1976).	
On arterials, when the V/C ratio exceeds 1.1, assume all traffic in excess of 1.1 times ideal capacity diverts to alternate arterial routes (adding an average of one-half mile to the total one-way trip length).			Travel impact assumption.	Diversions from severely congested arterials are much more profitable and likely than diversions from freeways.
II. TRAVEL SHIFTS FOR INDIVIDUAL SCENARIOS				
A. FREEWAY SCENARIOS				
	INCREASE IN FREEWAY:			
SCENARIO TITLE	BUS RIDERSHIP	CARPOOLS		
1. Expanded Express Bus Service in Mixed Freeway Traffic; Favorable Impacts	50%		Bus increase: roughly equal to increase in ridership reported for Seattle Blue Streak experience (see I.B of table for reference).	Daily Blue Streak patronage increased from 7,530 to 11,189, despite a 3.8% decrease in overall travel during same period.
2. Freeway Lane Reserved for Buses and Carpools; Favorable Impacts	100%	100%	Bus increase: Literature search findings for a similar strategy/program in Exhibit 3, 8: a 182% increase. Carpool increase: In Exhibit 3, 8, a 190% increase is reported.	100% chosen instead of 182% for Santa Monica experience because of the extremely low initial fraction transit in that case. 100% chosen instead of 190% reported; again, because of the very low initial fraction of carpools in that experience. Both increases are still fairly large, but consistent with the assumed initial modal split for the prototype corridor.

(Continued)

TABLE A.4

(CONTINUATION 3)

ANALYTICAL ASSUMPTIONS AND PROCEDURES			BASIS OR SOURCE	COMMENTS
	INCREASE IN FREEWAY:		(Continued)	
SCENARIO TITLE	BUS RIDERSHIP	CARPOOLS		
3. Ramp Metering and Bus By-Pass Lanes; Favorable Impacts	100%	–	Bus increase: Set at somewhat lower level than that achieved in scenario 7 (125%).	Scenario 7 should have a larger bus ridership increase because the bus travel time advantage should be greater for the contraflow lane strategy than the ramp metering and bus by-pass strategy under the prototype conditions.
4. Reserved Bus/Pool Lane, Ramp Metering, and Bus By-Pass Lanes; Modest Impacts	75%	50%	Increases were determined judgmentally, to be lower than those of scenario 5 (favorable impacts).	Although lower, these increases still reflect the relatively greater impact on bus ridership than on carpooling assumed in scenario 5.
5. Reserved Bus/Pool Lane, Ramp Metering, and Bus By-Pass Lanes; Favorable Impacts	125%	95%	Bus increase: Relative to scenario 2 (100%), addition of ramp metering and bus by-pass should increase the bus time advantage and thus the bus ridership increase.	Given limiting factors on maximum bus ridership increases (commuters with odd hours, inaccessible to transit, needing a car, etc.), a further increase of 25% over scenario 2 was considered as large as would be reasonable.
			Carpool increase: Chosen to be slightly smaller than scenario 2 value (100%).	Smaller value results from no increase in incentive for carpooling but increased competition from transit relative to scenario 2.
6. Contraflow Freeway Lane Reserved for Buses; Favorable Impacts	50%	–	Bus increase: Experiences reported in Exhibit 3, A show ridership increases of 14-44%. Selection of larger value for prototype case (50%) made for reasons to right.	Experiences for which information was available could be expected to have much lower increases because: • the base transit levels in documented demonstrations were already very high. • demonstrations were applied primarily to reduce localized a.m. peak congestion through use of underutilized off-peak direction capacity.
7. Contraflow Bus Lane, Expanded Express Bus Service, and Park-and-Ride Lots; Favorable Impacts	125%		Bus increase: Chosen to be greater than scenario 2 value (100%) and also greater than the sum of the impacts in scenarios 1 and 6, the constituents of scenario 7 (50% + 50% = 100%).	Increase should be greater than in scenario 2 because: • the contraflow bus only lane should provide a greater time advantage to buses than a bus/pool lane. • in scenario 7, buses are not competing against carpools for increases. Increase should be greater than sum of increases for separate parts of combination program since the travel time, access, and service area improvements should reinforce the impacts of each other.
8. Contraflow Bus Lane, Expanded Service, and Lots; Assuming 70%/30% Directional Split; Favorable Impacts	125%	–	Same as scenario 7.	The only difference between scenarios 7 and 8 are in the assumed off-peak direction vehicle volume on the freeway.

(Continued)

TABLE A.4

(CONTINUATION 4)

ANALYTICAL ASSUMPTIONS AND PROCEDURES		BASIS OR SOURCE	COMMENTS
B. ARTERIAL SCENARIOS			
SCENARIO TITLE	**RIDERSHIP INCREASE**		
9. Reserved Arterial Median Lane for Express Buses; Favorable Impacts	Express bus ridership achieved which yields overall bus modal split of 40% (local plus express).	Chosen to be greater than 30% bus modal split achieved in similar project on 7th Avenue in Miami (Exhibit 4, G).	Higher bus modal split (40%) chosen to reflect favorable impact assumption and substantial (15%) local bus market base which prototype corridor starts with before addition of express service.
10. Contraflow Curb Lane for Local Buses on Pair of One-Way Arterials; Favorable Impacts	15% increase in local bus ridership on arterials in peak direction.	Judgmental determination.	15% value chosen as reasonably optimistic given modest size of possible bus travel time savings, relatively large initial bus modal split, and fact that most trips will still probably be faster by auto for prototype case.

TABLE A.5:

ESTIMATING TRAVEL SHIFTS FOR REGIONAL PROTOTYPE SCENARIOS

<table>
<tr><th colspan="3">ANALYTICAL ASSUMPTIONS AND PROCEDURES</th><th>BASIS OR SOURCE</th><th>COMMENTS</th></tr>
<tr><td colspan="3">I. GENERAL, FOR SCENARIOS INVOLVING EMPLOYER CARPOOL/VANPOOL PROGRAMS
A. OVERALL APPROACH
Since the carpool/vanpool programs to be analyzed are employer based, the VMT impacts will be estimated on a "per employee" basis and then multiplied by assumed regional employment for the prototype region to obtain estimated change in weekday regional VMT. This regional reduction in VMT will then be distributed to level of service (average speed) and road-type categories so that emission and fuel consumption impacts can also be estimated.
The overall change in VMT consists of two components:
• non-circulatory – associated with the shift from many low occupancy vehicles to fewer high occupancy vehicles (carpools and vanpools). A reduction results.
• circulatory – associated with additional vehicle travel to drive to carpool meeting points and for picking up or dropping off non-driving pool members. An increase in VMT results.</td><td></td><td></td></tr>
<tr><td colspan="3">B. NON-CIRCULATORY VMT REDUCTION
The regional weekday change in non-circulatory VMT associated with carpool/vanpool programs is estimated by multiplying regional employment by an average VMT saving per employee associated with the program.
The per employee VMT saving factor is based on the assumed program participation rates; the change in vehicle occupancies associated with the shift to carpools and vanpools; and the average work trip lengths involved.
The values assumed in estimating the non-circulatory VMT change associated with areawide employer carpool/vanpool programs are as follows:</td><td>Adapted from analytical approach appearing in: Frederick Wagner, "Evaluation of Carpool Demonstration Projects" (Paper presented at Annual Meeting of the Federally Coordinated Program of Research and Development in Highway Transportation, Columbus, Ohio, Nov. 8, 1977).</td><td></td></tr>
<tr><td></td><td colspan="2">VALUE ASSUMED FOR ANALYSIS</td><td></td><td></td></tr>
<tr><td>QUANTITY</td><td>MEDIUM SIZED REGION</td><td>LARGE REGION</td><td></td><td></td></tr>
<tr><td>Regional employment</td><td>293,590</td><td>1,152,766</td><td>1970 U.S. Census Journey to Work data</td><td>Average number of SMSA workers in 28 regions in 500,000-1,000,000 population class (medium) and in the 23 regions in 1,000,000 + population group (large) reporting VMT for the National Transportation Study, respectively.</td></tr>
<tr><td>Average work trip length among those forming carpools</td><td>12 miles</td><td>16 miles</td><td>Medium: Exhibit 5, A2 reports range of 8.8-16.5. Average value for reported regions with appropriate populations in paper by Frederick Wagner is 11.11.
Large: Exhibit 5, A1 reports range of 6.3-22.3. Average for large cities in Wagner paper is 15.28</td><td>Chosen value of 12 is close to middle of reported range and slightly larger than average in Wagner paper, consistent with typical "favorable impact" assumption.
Chosen value reflects same guidelines as used for medium size region.</td></tr>
</table>

(Continued)

TABLE A.5

(CONTINUATION 1)

ANALYTICAL ASSUMPTIONS AND PROCEDURES			BASIS OR SOURCE	COMMENTS
			(Continued)	
	VALUE ASSUMED FOR ANALYSIS			
QUANTITY	MEDIUM SIZED REGION	LARGE REGION		
Average work trip length among those forming vanpools	25 miles	25 miles	Exhibit 5, C reports range of 18-38 miles. No distinction based on region size.	Value of 25 miles selected to be near middle of reported range. Economic feasibility requirements of vanpools are more relevant than region's overall average trip lengths.
Average carpool vehicle occupancy	3.1	2.9	Medium: Exhibit 5, A2 reports range of 2.9-3.3.	Median of range chosen.
			Large: Wagner paper reports a 2.30-3.02 range with a 2.8 average.	Value of 2.9 chosen was slightly above middle of range, reflecting favorable impacts assumption and comparison with value for "medium."
Average vanpool vehicle occupancy	11	11	Exhibit 5, C suggests an average of about 11.	Economic feasibility requirements of vanpools are more relevant than any regional variation in average vehicle occupancy.
Average overall commuter vehicle occupancy	1.25	1.20	Medium: Exhibit 5, A2 reports range of 1.0-1.8. Wagner paper yields average of 1.29.	Chosen value is slightly below reported average and at lower end of reported range to reflect favorable impact assumption of base analysis.
			Large: Exhibit 5, A1 reports range of 1.14-1.42. Wagner paper yields average of 1.23.	Chosen value is slightly below reported average and middle of reported range to reflect favorable impact assumption of base analysis.
Carpool participation rate; estimated number of new carpool members per regional employee as a result of program	0.0273	0.0256	Medium: (See notation to right) X chosen as 0.022 from range of .017-.024 reported in Exhibit 5, A2. Y chosen as 0.40 from range of .17-.54 reported in Exhibit 5, A2. Somewhat higher than estimate for Sacramento that 33% of employees are of employers of 200 or more (Peat, Marwick, Mitchell & Co, Carpooling Impact Study). CPOCC as above. Large: X chosen as 0.25 from range of .013-.074 (clustered more toward lower end) reported in Exhibit 5, A1. Y chosen as 0.35 from range of .16-.42 reported in Exhibit 5, A1. Approximately equal to estimate for Chicago that 38% of employees are of employers of 200 or more (PMM&Co., Carpooling Impact Study).	Rate calculated as product of: • ratio of new permanent carpools formed to exposed employees (X); • fraction of total regional employees exposed (Y); and • average assumed carpool occupancy (CPOCC). Values of individual factors chosen to reflect reasonably favorable impacts in light of: • competition from vanpooling component of program (not usually present for documented experiences on an areawide scale); and • fact that documented experiences tend to be representative of high motivation and favorable conditions.

(Continued)

TABLE A.5

(CONTINUATION 2)

ANALYTICAL ASSUMPTIONS AND PROCEDURES			BASIS OR SOURCE	COMMENTS
	VALUE ASSUMED FOR ANALYSIS		(Continued)	
QUANTITY	MEDIUM SIZED REGION	LARGE REGION		
Vanpool participation rate; estimated number of new vanpool members per regional employee as a result of program	0.006	0.005	(See notation to right). For X: "Marketing Plan to Accelerate the Use of Vanpools" (FEA, July 1978) states that most vanpool participation rates tend to cluster in area of 3-8% of exposed employees. Low end value of 0.03 chosen. For Y: Survey tabulation results from Carpooling Impact Study (PMM&Co.) on percent of employees working for employers of 1,000 or more at a site were used. Medium: 20% value for Sacramento used. Large: 17% value for Chicago used.	Rate calculated as product of: • fraction of exposed employees who form new permanent vanpools (X); and • fraction of total regional employment estimated to be exposed – working for employers of 1,000 or more at a site (Y). Value of vanpool participation rate (X) chosen at low end because: • documented experiences rarely included strong competition from a carpool program; and • documented experiences tend to be for single large employers with high motivation under favorable conditions.
C. ALLOCATION OF VMT REDUCTION				
The regional reduction in non-circulatory weekday VMT is allocated to level of service (average speed), road type, and vehicle type categories as follows:				
• The reduction is assumed to be taken entirely from the "automobile" vehicle type category.			Assumption	Bus VMT (service) is not likely to change significantly in response to program. A successful program will minimize shifts to pools from transit.
• All non-circulatory VMT reductions are assumed to be on freeway and arterial roadways (local and collector roads excluded).			Assumption	Little of line haul portion of work trip is likely to take place on local roads.
• The VMT reduction is distributed between freeway and arterial road types and among level of service (average speed) categories in proportion to the base VMT distribution for the prototype region.			Assumption	The VMT changes likely to result would not significantly change average speeds on specific facilities.
D. CIRCULATORY VMT INCREASE				
The regional weekday change in circulatory (access and passenger pick-up and drop-off) VMT associated with carpool/vanpool programs is estimated as:				
$\Delta VMT_c = 2\,NEMP\left[CFAC_{CP} * CPPR + CFAC_{VP} * VPPR\right]$			Formula developed for report analysis.	
where: ΔVMT_C = change in circulatory regional weekday VMT associated with program NEMP = regional employment CPPR = carpool participation rate VPPR = vanpool participation rate (NEMP, CPPR, VPPR: See section I.B, above)				

(Continued)

TABLE A.5

(CONTINUATION 3)

ANALYTICAL ASSUMPTIONS AND PROCEDURES	BASIS OR SOURCE	COMMENTS
$CFAC_{CP}$ = is a circulatory factor representing the additional access, pick-up, and/or drop-off VMT *per occupant* associated with the formation of a new carpool $CFAC_{VP}$ = analogous to $CFAC_{CP}$, for new vanpools The value of $CFAC_{CP}$ was estimated on the basis of survey data on the number of additional blocks driven by carpools to pick up and drop off members, average carpool occupancy, and the following assumptions: • 1 block = 1/10 mile • survey responses citing a pick-up distance of 0 blocks should be ignored as pertaining to "household" carpools, unlikely to be affected by pool matching programs.	(Continued)	
In the absence of better available data, the value of $CFAC_{VP}$ is assumed to be equal to that of $CFAC_{CP}$: Medium Size Region / Large Region $CFAC_{CP}$ = $CFAC_{VP}$: 0.38 mile / 0.22 mile	Survey data from PMM&Co. *Carpooling Impact Study* on length in blocks of additional carpool pickup and drop-off travel.	Sacramento survey results were used for the medium sized prototype region. Chicago survey results were used for the large prototype region.
The overall VMT increase was distributed, by the appropriate vehicle type (carpool or vanpool), to the following three circulatory road type/average speed categories used to estimate emissions and fuel consumption impacts: Percent of Total VMT # Road Type / Average Speed / Medium Region / Large Region 1 Local / 15 mph / 42% / 64% 2 Arterial / 25 mph / 28% / 18% 3 Arterial / 15 mph / 32% / 18%	Based on above survey data and following assumptions: • All residential end travel of 5 block or less on local roads, 15 mph assumed average speed. • Residential end travel in excess of 5 blocks is ½ on local roads and ½ on arterial roads of 25 mph average speed. • All employment end travel on more congested 15 mph arterials.	
II. GENERAL, FOR SCENARIOS INVOLVING MULTIPLE APPLICATION OF FREEWAY CORRIDOR STRATEGIES A. OVERALL APPROACH As with the VMT changes associated with carpool/vanpool programs, the VMT changes resulting from freeway corridor strategies have both non-circulatory and circulatory components.		Circulatory VMT increases include additional travel associated with access to express bus collection points for those strategies resulting in express bus ridership increases.
B. NON-CIRCULATORY VMT CHANGES The reduction in regional weekday non-circulatory VMT is calculated by applying the percentage shifts used for vehicle volume in the corresponding localized scenario instead to the appropriate "affected" VMT categories. VMT reductions occur because of the higher average occupancies of the vehicle types experiencing VMT increases (at the expense of greater VMT decreases for the low occupancy modes).	Travel Impact Assumption.	

(Continued)

TABLE A.5
(CONTINUATION 4)

<table>
<tr><th>ANALYTICAL ASSUMPTIONS AND PROCEDURES</th><th>BASIS OR SOURCE</th><th>COMMENTS</th></tr>
<tr><td>"Affected VMT" for the freeway corridor regional scenarios is a subset of total regional VMT. It represents that regional freeway VMT estimated to be directly affected by the relevant strategies plus the VMT estimated to be on arterials serving the same radial corridors.</td><td>(Continued)</td><td></td></tr>
<tr><td>For the large prototype region, the "affected" weekday freeway VMT was estimated at 1,073,100.</td><td>Analytical assumptions.</td><td>The total regional weekday freeway VMT of 12,304,800 was reduced as follows:
• Only 30% is peak period.
• Only 60% of this in peak direction.
• Only about ½ of this VMT is assumed to be associated with radial freeways whose geometrics and base congestions are appropriate for reserved lane strategies.</td></tr>
<tr><td>The associated arterial VMT was estimated at 735,900.</td><td>Analytical assumption.</td><td>This bears the same relation to the above affected freeway VMT as the ratio of corridor arterial to corridor freeway vehicle volume assumed in the 8 lane freeway localized prototypes.</td></tr>
<tr><td>These VMT totals were distributed across vehicle types and level of service classes exactly as was done for total regional base VMT, except that VMT in the A and F level of service classes was precluded as being inconsistent with conditions appropriate for implementing reserved lane strategies.</td><td>Analytical assumption.</td><td></td></tr>
<tr><td>Following the calculation of non-circulatory VMT reductions and allocation to vehicle type and initial level of service classes, shifts among level of service classes were made to simulate congestion effects.</td><td></td><td>After the VMT shifts associated the scenario strategy were made, the new V/C ratio for each tentative LOS class is calculated. If the new value is no longer in the range for the class, all of the VMT in that tentative LOS class is shifted to the LOS class appropriate for that V/C ratio.</td></tr>
<tr><td>C. CIRCULATORY VMT INCREASES
Associated with each shift to high occupancy vehicles induced by a freeway strategy is assumed to be an increase in circulatory VMT – travel associated with modal access or passenger pick-ups and drop offs. The following table presents the assumed rates used to calculate circulatory VMT increases associated with the strategy-induced modal shifts:</td><td></td><td></td></tr>
<tr><td>
<table>
<tr><th colspan="2">CORRIDOR MODAL SHIFT</th><th colspan="3">INCREASE IN CIRCULATORY VMT</th></tr>
<tr><th>FROM (SOURCE)</th><th>TO</th><th>ON 15 M.P.H. LOCAL</th><th>ON 25 M.P.H. ARTERIAL</th><th>ON 15 M.P.H. ARTERIAL</th></tr>
<tr><td>AUTO</td><td>CARPOOL</td><td>1.0% of Source VMT Shift</td><td>0.3% of Source VMT Shift</td><td>0.3% of Source VMT Shift</td></tr>
<tr><td>AUTO</td><td>EXPRESS BUS</td><td>2.5% of Source VMT Shift</td><td>7.5% of Source VMT Shift</td><td>–</td></tr>
<tr><td>LOCAL BUS</td><td>EXPRESS BUS</td><td>1.25% of Source VMT Shift</td><td>3.75% of Source VMT Shift</td><td>–</td></tr>
<tr><td>"NEW TRIP"</td><td>EXPRESS BUS</td><td>.25 mile Per Person</td><td>.75 mile Per Person</td><td>–</td></tr>
</table>
</td><td>Analytical assumptions</td><td>For shifts to carpools: Based on: (a) assumed additional per person travel for pool access and passenger pick-up and drop-off (.25 mile per person); (b) assumed average carpool trip length (16 miles – assumed carpool trip length for large region); and (c) assumed distribution of increase among road types – 64% on local roads at 15 mph; 18% on 25 mph arterials; and 18% on 15 mph arterials (same assumption as that used for carpool/vanpool programs).</td></tr>
</table>

(Continued)

TABLE A.5

(CONTINUATION 5)

ANALYTICAL ASSUMPTIONS AND PROCEDURES	BASIS OR SOURCE	COMMENTS
	(Continued)	For shifts to express bus: Based on: (a) assumed additional per person travel for bus access of 1 mile from auto and 0.5 mile from local bus; (b) 10 mile assumed average trip length; and (c) assumed distribution of increase of 25% on local roads at 15 mph and 75% on 25 mph arterials (no change at work end of trip). For new trips by express bus: Based on: (a) assumed 1 mile extra travel per person and (b) same 25%/75% distribution to local roads and 25 mph arterials as above.
III. GENERAL, FOR SCENARIOS INVOLVING MULTIPLE APPLICATION OF ARTERIAL MEDIAN RESERVED LANE STRATEGIES		
A. OVERALL APPROACH The methodology and assumed values are the same as for freeway strategies outlined in section II of this table, with the exceptions given below.		
B. NON-CIRCULATORY VMT CHANGES "Affected VMT" for the arterial corridor regional scenarios is that regional arterial VMT estimated to be directly affected by the relevant reserved median bus lane strategies.		
For the large prototype region, the "affected" weekday freeway VMT was estimated at 720,000. The percent distribution of this VMT by vehicle types was assumed to be the same used in the localized median bus lane scenario (see table A.2, section II.)	Analytical assumptions.	The 1,073,000 "affected" freeway VMT for the regional freeway strategies corresponds to travel on roughly four, 10 mile radial freeways. In the same type of large prototype region, it is assumed that roughly 8 major radial arterials with an average length of 9 miles would be appropriate for application of the arterial strategy. The "affected" VMT estimate is based on this 72 miles of roadway; an assumed average peak hour volume of 2,000 vph (down from 2,250 vph assumed for segment 1 mile from CBD in localized prototype scenarios); and a factor of 5 to convert peak hour to a.m./p.m. peak periods travel.
C. CIRCULATORY VMT CHANGES In addition to the changes outlined for the regional freeway corridor scenarios, increases in VMT associated with congestion-induced route diversions were also estimated when the V/C ratio for any group of VMT was estimated to exceed 1.1.	Analytical assumption.	

(Continued)

TABLE A.5
(CONTINUATION 6)

ANALYTICAL ASSUMPTIONS AND PROCEDURES	BASIS OR SOURCE	COMMENTS
That portion of any affected VMT estimated to exceed the 1.1 value for V/C was assumed diverted to alternate arterial routes operating at E level of service. In addition, another 28% (of this diverted VMT) was also added to the 15 mph arterial total as an approximation of the additional travel associated with the route diversions.	(Continued)	The 28% route diversion circuitry factor was based on (a) an assumed additional travel of ½ mile each way because of the diversion; (b) a 9 mile arterial length; and (c) an assumed 20% of the arterial length operating at E level of service (those portions from which the diversions are most likely).
II. TRAVEL SHIFTS FOR INDIVIDUAL SCENARIOS **A. CARPOOL/VANPOOL PROGRAM SHIFTS** The travel shifts resulting from employer carpool/vanpool programs were calculated using the methodology and assumptions of section I, B of this table in all regional scenarios containing a carpool/vanpool program.		For those scenarios with "modest" instead of "favorable" impact assumptions, the base ("favorable") travel impacts are scaled down by a factor of ½ (corresponding to an assumed halfing in the program participation rates).
B. FREEWAY AND ARTERIAL CORRIDOR SHIFTS Each multiple application freeway or arterial corridor strategy in the regional scenarios corresponds to one or more of the strategies or combination programs in the ten localized scenarios. When an exact match (in terms of strategy and assumed impact level – modest or favorable) existed between the corridor component of a regional scenario and one of the localized scenarios, then the regional corridor VMT impacts were estimated as follows: • for each specific mode-to-mode vehicle volume shift estimated in the localized scenario, an analogous mode-to-mode VMT shift is estimated for the regional scenario; • the percent of base "affected" source mode VMT shifting in each case is assumed to be the same as the corresponding percent vehicle volume shift in the localized scenario; and • VMT reductions result because the average vehicle occupancy of the "receiving" mode is higher than that of the source mode. For some regional scenarios, an exact match with one of the localized scenarios did not exist. In these cases, adjustments in the most closely matching localized scenario shifts were made, as follows:	Analytical assumptions.	
• Scenario 15: To simulate the modest impacts assumption for this strategy, for which only a favorable impact localized scenario counterpart exists, travel shifts resulting from a 30% (instead of 40%) final corridor bus modal split were used.	Travel impact assumptions.	
• Scenario 17: To simulate the modest impacts assumption for this strategy, for which only a favorable impact localized scenario counterpart exists (Scenario 2), travel shifts resulting from a 55% increase in affected express bus VMT and a 65% increase in affected carpool VMT were used in place of the 100%/100% assumed shifts in Scenario 2.		The 55%/65% values reflect the assumption that carpooling will tend to be more attractive than express bus under modest impact conditions. These values also yield approximately the same modest/favorable impact ratio for scenario pair 17 and 18 as achieved for scenario pair 13 and 14.

TABLE A.6:

ESTIMATING HIGHWAY EMISSIONS

I. GENERAL APPROACH

Estimates of regional highway emissions and line source emission intensity were made by applying January, 1978 vehicle exhaust emission factors published by the U.S. Environmental Protection Agency, Office of Transportation and Land Use Policy. Individual emission factors were computed by means of an EPA computer program, based on methodology and (updated) parameters appearing in Mobile Source Emission Factors, Interim Document, June, 1977 (EPA, OTLUP).

Except as specified below, average default values were used in calculating the emission factors.

II. VEHICLE TYPE CONVENTIONS

Emission factors were separately calculated and applied to the following standard EPA vehicle types:

LDV – light duty vehicle
LDT$_1$ – light duty truck (under 6,500 lbs.)
LDT$_2$ – light duty truck (6,500-8,500 lbs.)
HDG – heavy duty gasoline vehicle
HDD – heavy duty diesel vehicle

The four basic vehicle types used for travel impact estimation purposes in this report were equivalenced to the above standard EPA categories as follows:

Auto = LDV
Carpool = LDV, assumed to carry 500 lbs. additional weight
Bus = HDD

Truck totals are allocated among four EPA standard classes according to the following assumed urban truck distribution:

$\#\ \text{LDT}_1 = \#\ \text{Trucks} \times 6/14$
$\#\ \text{LDT}_2 = \#\ \text{Trucks} \times 6/14$
$\#\ \text{HDG} = \#\ \text{Trucks}/14$
$\#\ \text{HDD} = \underline{\#\ \text{Trucks}/14}$
$\#\ \text{Trucks}$

III. HOT AND COLD START ASSUMPTIONS

For a.m. peak hour regional emissions calculations, the following distribution of vehicle operating conditions are assumed for all vehicle and facility types:

20%	cold start
10%	hot start
70%	stabilized

For a.m. peak hour line source emission intensity calculations, the following distributions of vehicle operating conditions were assumed for the CO impact area (approximately 1 mile out from the CBD):

Type of Traffic	Cold	Hot	Stable
Buses, inbound freeway	–	–	100%
Buses, outbound freeway	5%	5%	90%
Other inbound freeway vehicles	15%	5%	80%
Other outbound freeway vehicles	20%	15%	65%
All inbound arterial vehicles	10%	5%	85%
All outbound arterial vehicles	20%	15%	65%

IV. ARTERIAL FLOW ADJUSTMENT FACTOR

Given the illustrative, prototype nature of the analysis, it was inappropriate to attempt detailed queue formation and intersection analyses to account for the impact of traffic controls and intersection conflicts on arterial emission rates (over and above the impacts reflected in average speed). However, it was nevertheless important in calculating arterial emissions to at least generally take into account these stop-and-go conditions which differentiate arterials from "slow freeways."

A microscale analysis of a typical arterial intersection was conducted to estimate the additional emissions associated with intersection delay. The results of this analysis indicated that four-way queuing at arterial intersections increased arterial emissions by an average of 43% over what they would have been at the same average speeds without the intersection delays. This emission increment factor was applied to all calculations for arterials and local streets to account for these intersection effects.

V. REGIONAL EMISSION ESTIMATES

Estimates of regional HC, NO_x and CO emissions were made by multiplying the projected signed changes in weekday regional VMT (disaggregated by average speed, facility type, and vehicle type) by the corresponding emissions rates and summing over all disaggregation types.

VI. LINE SOURCE EMISSION INTENSITY ESTIMATES

In order to make estimates of the localized CO concentration impacts of corridor-oriented strategies, it is first necessary to estimate the line source intensity of CO emissions for the affected freeway and/or arterial facilities. After total projected vehicle volume on a facility is allocated to the separate lanes on the basis of the scenario specifications and typical lane distributions, the line source emission intensity (e.g., μgm./meter-sec.) is calculated for each lane by multiplying lane volume by the appropriate composite CO emission factor. This composite factor corresponds to the vehicle type, mode of operation, average speed, and temperature assumed.

(Continued)

TABLE A.7:

ESTIMATING LOCALIZED CO CONCENTRATION IMPACTS

I. EPA HIWAY MODEL ESTIMATES

The CO line source emission intensities discussed in Table A.6 are input to a modified version of the EPA HIWAY model to provide estimates of a.m. peak hour CO concentrations associated with the emissions from the affected highway facilities. Unlike the standard version of HIWAY, which calculates CO concentrations at 5 specified receptors, the modified version calculates concentrations for an 11 x 11, 121 receptor grid, set to cover a mile square area.

The prototype corridor facilities were oriented within the grid so that the primary corridor facility runs parallel to the grid point rows and so that the maximum concentration receptor is located 50 feet (along the perpendicular) downwind from the edge of the primary facility. Level topography is assumed in the model.

For each localized scenario, HIWAY model estimates of grid point CO concentrations were made for each of the three meteorological conditions defined in Exhibit 11.

II. AVERAGE EIGHT HOUR CO CONCENTRATIONS

Although CO concentration impact estimates were made only for the a.m. peak hour, attainment of the national standard for maximum average eight hour CO concentrations is an important consideration in some areas.

Exhibit 14 can be used to estimate the maximum 8-hour CO concentration (including background CO) using the estimated peak 1-hour CO concentrations (from vehicular traffic only) in Exhibits 13 through 15. A background CO concentration of 5,714 ug/m^3 (5 ppm) and a 0.7 ratio of peak 8-hour to peak 1-hour CO concentrations were used to develop Exhibit 14. The source of these factors is:

> GCA Corporation. Identification and Evaluation of Localized Violations of Carbon Monoxide Standards - Volume I: Guidelines (Draft Final Report). Prepared for EPA - Region I Office. November 1975, pgs. II-12 and II-13.

TABLE A.8:

ESTIMATING REGIONAL FUEL CONSUMPTION IMPACTS

I. CALCULATION PROCEDURE

The change in weekday regional fuel consumption in gallons is estimated by multiplying the signed projected weekday VMT changes for a scenario (disaggregated by facility type, vehicle type, and level of service/average speed class) by the corresponding disaggregate fuel consumption rate and summing these products over all of the disaggregation classes.

The change in annual regional fuel consumption is estimated as 250 (number of work days per year) times the weekday value, since all of the scenario strategies are essentially work day strategies.

II. DISAGGREGATE FUEL CONSUMPTION RATES

The fuel consumption rates used in the analysis were estimated from fuel consumption and vehicle type distribution data appearing in Characteristics of Urban Transportation Systems (July, 1977 version) as follows:

Table 3-6: bus fuel consumption rates
Table 4-5: auto and truck fuel consumption rates and vehicle type distribution on freeways
Table 4-6: auto and truck fuel consumption rates and vehicle type distribution on arterial streets

The average speeds by level of service class appearing in Table A.3, IA were used so that the fuel consumption rates could be expressed and applied directly in terms of level of service class.

Local streets were assumed to be arterial streets for fuel consumption calculation purposes.

Fuel consumption rates for speeds beyond the range of speeds for which rates were available were assumed to be the rates for the closest reported speed. Rates for speeds between reported speeds were estimated through linear interpolation.

A 2% roadway grade was assumed for buses in estimating fuel consumption rates.

Vanpools were assumed to be 2-ton light duty trucks for the purpose of fuel consumption estimation.

TABLE A.9

ILLUSTRATIVE CALCULATION OF TRAVEL SHIFTS

This section illustrates how the procedures and assumptions cited in Table A.1 – A.5 were used to estimate travel impacts for the localized and regional scenarios. Scenarios 5 and 12 are cited as representative localized and regional scenarios, respectively.

I. Localized Scenario Travel Shifts (Scenario 5)

A. "Before" Peak Hour Travel Conditions

Exhibit 10 presents the distribution of "before" condition vehicles by type. This distribution was further stratified as shown below, using assumptions shown in item D of Table A.2.

	Vehicle Type	Vehicles per Hour*		Persons per Hour**
Freeway:	Single Occupant Auto	4,967	6,290	4,967
	Two Occupant Auto	1,323		2,648
	Three(+) Occupant Auto (Carpools)	330		1,192
	Express Bus	26		1,170
	Local Bus	–		–
	Trucks	350		–
Corridor Arterials:**				
	Single Occupant Auto	3,363		3,363
	Two Occupant Auto	897		1,794
	Three(+) Occupant Auto (Carpools)	224		806
	Express Bus	–		–
	Local Bus	78		4,290
	Trucks	238		–

* From Exhibit 10.

** From project working papers.

B. Travel Impact Assumptions

Assumed percentage increases in freeway bus ridership and carpools of 125 percent, and 95 percent, respectively, for scenario 5 are taken from Table A.4.

C. Peak-Hour Carpool Shifts

"New" Carpools on Freeway = (.95)(330) = 314 carpools in peak hour. This represents 1,130 persons in carpools using an average carpool occupancy of 3.6.

TABLE A.9 (Continued)

Based on Item C of Table A.4, the increase in carpools and the corresponding reduction in vehicular volumes on arterials and freeways were achieved from the following sources:

Source of Carpools	Percent of[*] New Carpoolers	New Carpools	Vehicle Reductions by Occupancy Class 1	2	3(+)	Total
Arterial Carpools	10	31	–	–	31	31
Arterial Auto (1, 2 occupant)	18	57	133[**]	36[**]	–	169[**]
Freeway Auto (1, 2 occupant)	72	226	530[**]	142[**]	–	672[**]
	100	314				872

[*] From Item C of Table A.4.

[**] As noted in Item C of Table A.4, shifts from 1 and 2 occupant autos to carpools were allocated in proportion to the base number of persons in each occupancy class shown in A. above.

D. Peak Hour Transit Ridership Shifts

Increase in peak hour transit ridership on freeways = (1.25)(1,170) = 1,463 riders. Total peak hour transit ridership on the freeway = 2,633 riders (1,170 (i.e., base) + 1,463 (i.e., increase)).

Using an average load factor of 40 riders per bus, an estimated 66 express buses are assumed to operate on the reserved freeway lane during the peak hour under the "after" conditions. This is 40 more buses than in the "before" condition.

Based on Item B of Table A.4, the increase in transit ridership and the corresponding reduction in vehicular volumes on arterials and freeway were achieved from the following sources:

Source of Transit Ridership	Percent of[1] New Transit Riders	New Riders	Vehicle Reductions by Occupancy 1	2	3(+)	Total
Induced	*	146	–	–	–	–
Local (Arterial) Bus	20#	263	–	–	–	–
Arterial Auto (1, 2 occupant)	16#	211	118[@]	32[@]	8[@]	158[@]
Freeway Auto (1, 2 occupant)	64#	843	549[@]	147[@]	–	696[@]
		1,463				854

TABLE A.9 (Continued)

[1] From Item B of Table A.4.

* Assumed as 10% of 1,463 new transit riders.

# Percentages apply to non-induced (1,463 – 146 = 1,317) increase in transit ridership.

@ As noted in Item B of Table A.4, shifts from 1, 2 and 3+ occupant autos to transit were allocated in proportion to the base number of persons in each occupancy class shown in A. above.

E. Peak Hour Freeway Traffic Volume Shifts

The impact of the above carpool and transit shifts on peak hour, peak direction freeway traffic volumes is presented below.

Vehicle Type	"Before" Vehicles* per Hour	Vehicle Changes on Freeway from Carpool Shifts	Vehicle Changes on Freeway from Transit Shifts	"After" Vehicles* per Hour (unrounded)
Auto	6,290	–672	–696	4,922
Carpool	330	+314	–	644
Bus	26	–	+40	66
Trucks	350	–	–	350

* See Exhibit 10 for these estimates.

F. Peak Hour Corridor Arterial Traffic Volume Shifts

Peak hour traffic volume shifts on corridor arterials which are reported in Exhibit 10 were estimated using the same process presented above for freeways.

G. Operating Speed Estimates for Freeway

As noted in Item B of Table A.2, average vehicle operating speeds for the reserved and non-reserved freeway lanes were estimated based on computed volume to capacity (v/c) ratios for each scenario.

For scenario 5, the "before" and "after" peak hour vehicle volumes (from point E above), hourly capacities, V/C ratios, and corresponding average peak hour operating speeds for the reserved and non-reserved lanes in the peak-direction of travel are presented below:

Freeway	Peak Hour, Peak Direction, Volume (Unrounded)	Hourly Capacity (VPH)	V/C Ratio	Average* Operating Speed (MPH)
"Before" Condition				
. Non-Reserved Lanes	6,996	7,000	1.00	28
"After" Condition				
. Non-Reserved Lanes	5,272	5,250	1.00	30**
. Reserved Lanes	710	1,750	0.41	43

* Tables 33 and 34 of the report Characteristics of Urban Transportation Systems (1974 edition) and the Highway Capacity Manual were used to estimate operating speeds.

** Assumes that ramp metering will result in a small improvement in average peak hour vehicle operating speed (i.e., from 28 to 30 mph) even though the V/C ratio in non-reserved lanes equals 1.0 in both the "before" and "after" conditions.

TABLE A.9 (Continued)

II. Regional Scenario Travel Shifts (Scenario 12)

A. Travel Assumptions

The assumed travel, trip length and employment characteristics used to estimate travel shifts in this scenario are presented in item B of Table A.5. These assumptions are summarized for convenience below:

QUANTITY	VALUE ASSUMED FOR ANALYSIS LARGE REGION
Regional employment	1,152,766
Average work trip length among those forming carpools	16 miles
Average work trip length among those forming vanpools	25 miles
Average carpool vehicle occupancy	2.9
Average vanpool vehicle occupancy	11
Average overall commuter vehicle occupancy	1.20
Carpool participation rate; estimated number of new carpool members per regional employee as a result of program	0.0255
Vanpool participation rate; estimated number of new vanpool members per regional employee as a result of program	0.005

B. Non-Circulatory VMT Change

The above estimates were used in conjunction with the following formula to estimate the change in regional weekday non-circulatory VMT associated with the carpool/vanpool program:

$$\Delta VMT_{NC} = 2\,NEMP\left[\left(\frac{CPTL}{CPPOCC} - \frac{CPTL}{BOCC}\right) CPPR + \left(\frac{VPTL}{VPOCC} - \frac{VPTL}{BOCC}\right) VPPR\right]$$

TABLE A.9 (Continued)

where:

ΔVMT_{NC} = change in non-circulatory regional weekday VMT associated with program
NEMP = regional employment
CPTL = average work trip length among those forming carpools
VPTL = average work trip length among those forming vanpools
CPOCC = average carpool vehicle occupancy
VPOCC = average vanpool vehicle occupancy
BOCC = average overall commuter vehicle occupancy
CPPR = carpool participation rate; estimated number of new carpool members per regional employee as a result of program
VPPR = analogous to CPPR, for vanpools

The calculation of this change is shown below:

$$\Delta VMT_{NC} = 2(1{,}152{,}766)\left[\left(\frac{16}{2.9}-\frac{16}{1.2}\right)(.0255)+\left(\frac{25}{11}-\frac{25}{1.2}\right)(.005)\right] = -673{,}446$$

C. Circulatory VMT Change

The regional weekday change in circulatory (access, passenger pick-up and drop-off) VMT associated with carpool/vanpool programs was estimated using the following formula (see item D of Table A.5):

$$\Delta VMT_C = 2\ NEMP\ [CFAC_{CP} * CPPR + CFAC_{VP} * VPPR]$$

where:

NEMP, CPPR, AND VPPR are as in section A above.

ΔVMT_C = change in circulatory regional weekday VMT associated with program
$CFAC_{CP}$ = is a circulatory factor representing the additional access, pick-up, and/or drop-off VMT per occupant associated with the formation of a new carpool
$CFAC_{VP}$ = analogous to $CFAC_{CP}$, for new vanpools

The value of $CFAC_{CP}$ was estimated on the basis of survey data on the number of additional blocks driven by carpools to pick-up and drop-off members, average carpool occupancy, and the following assumptions:

- 1 block = 1/10 mile; and
- survey responses citing a pick-up distance of 0 blocks should be ignored as pertaining to "household" carpools, unlikely to be affected by pool matching programs.

TABLE A.9 (Continued)

In the absence of better available data, the value of $CFAC_{VP}$ is assumed to be equal to that of $CFAC_{CP}$:

$$CFAC_{CP} = CFAC_{VP} : \frac{\text{Large Region}}{\text{0.22 mile}}$$

The calculation of this change is shown below:

$$\Delta\ VMT_C = 2(1{,}152{,}766)[(.22)(.0255) + (.22)(.005)]$$

$$\Delta VMT_C = +15{,}447$$

D. Total Weekday Regional VMT Change

$$\begin{aligned}\text{Total Change in VMT} &= \Delta VMT_{NC} + \Delta VMT_C\\ &= -673{,}446 + 15{,}447\\ &= -657{,}999\end{aligned}$$

$$\text{The percent reduction in VMT} = \left(\frac{657{,}999}{43{,}944{,}599}\right) 100 = 1.5\%$$

E. VMT Distribution by Facility Type

Tables A.3 and A.5 (items C and D) describe how the change in weekday regional VMT was allocated by level of of service (i.e., speed), road type, and vehicle type.

APPENDIX B

UNIT COST ASSUMPTIONS

ITEM	COST (in 1976 Dollars)	SOURCE
1. Bus Capital Cost (47-51 Passengers)	$66,000	DeLeuw, Cather & Co. and Rock Creek Associates. Characteristics of Urban Transportation Systems: A Handbook for Transportation Planners. Prepared for UMTA. July 1977. Page III-18, Table 3-14.
2. Bus Operating and Maintenance Cost	$1.49 per bus mile for population service areas of 750,000 - 2,500,000	DeLeuw, Cather & Co. and Rock Creek Associates. Characteristics of Urban Transportation Systems: A Handbook for Transportation Planners. Prepared for UMTA. July 1977. Page III-7, Table 3-5.
3. Park and Ride Lot		
A. Capital	$1,080 land and construction cost/stall (in 1976 dollars); this is based on a land cost of $2 per square foot	DeLeuw, Cather & Co. and Rock Creek Associates. Characteristics of Urban Transportation Systems: A Handbook for Transportation Planners. Prepared for UMTA. July 1977. Page IV-22, Table 4-15.
B. Operating and Maintenance Cost	$165 annual operating cost/stall (in 1976 dollars); includes property tax allowance.	
4. Bus Ramps	$759,244 (in 1972 dollars) for 9 bus ramps; 114,815 per ramp (in 1976 dollars)	Butler-Rivgrose-Wolsfield, Inc. Final Report for the I-35W Urban Corridor Demonstration Project. Prepared for UMTA. August 1975.
5. Contra-Flow Arterial Lane	$9,200/1.5 miles for sizing, striping, etc.	NCHRP Report 143, Bus Use of Highway State of Art. 1973. Page 251, Table C-8.
6. Reserved Freeway Bus/Carpool Lane		
A. With-Flow	$100,000 capital cost for Santa Monica Freeway $22,000 per mile annual operating cost (Assumption)	Urban Mass Transportation Administration. Service and Methods Demonstration Program Annual Report. April 1977. Page 237.
B. Contra-Flow	$50,000 per mile used based on several projects $22,000 per mile used based on several projects	DeLeuw, Cather & Co. and Rock Creek Associates. Characteristics of Urban Transportation Systems: A Handbook for Transportation Planners. July 1977. Page III-17, Table 3-13.

APPENDIX B (Continued)

ITEM	COST (in 1976 Dollars)	SOURCE
Ramp Metering	$27,200 per ramp for capital and installation (based on traffic-response system cost range of $15,000-30,000 in 1972 dollars) Annual operating and maintenance cost = $2,042 per ramp (based on $1,500 per ramp in 1972 dollars)	P. Everall, Urban Freeway Surveillance and Control: The State of the Art. Prepared for FHWA. November 1972. Page 143.